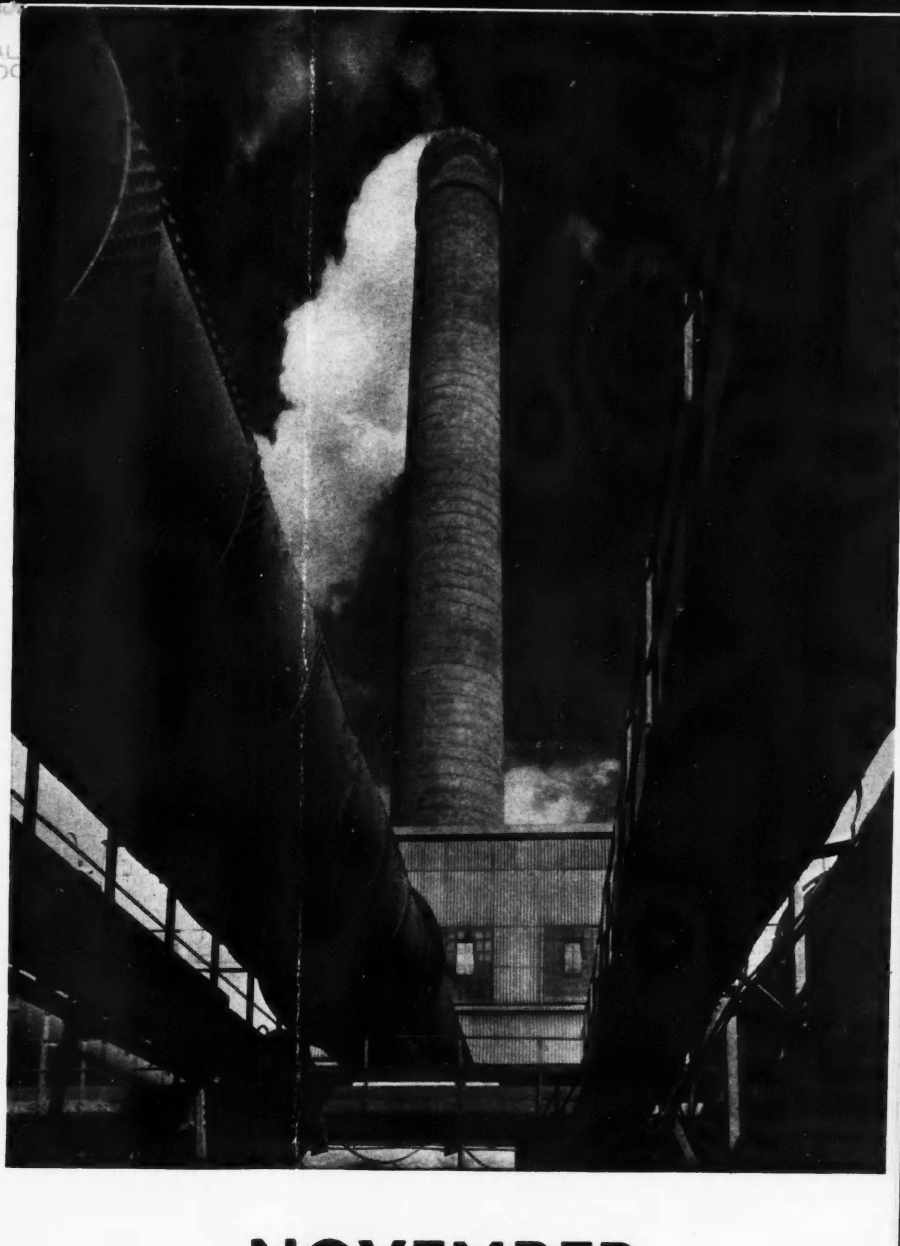
DISCOVERY



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Remarkable Advance in Electron Microscopy

METROPOLITAN-VICKERS DEVELOP LOW PRICE INSTRUMENT FOR GENERAL INDUSTRIAL RESEARCH AND TESTING

THE successful development by Metropolitan-Vickers of a low price Electron Microscope brings within the reach of general industry a remarkable scientific tool for industrial research and testing. Metrovick pioneered the development of the electron microscope in this country, their first instrument being completed 1935/36 and remaining the sole British electron microscope until 1940. Metrovick post-war research has resulted in two successive designs, EM2 and EM3, each being a remarkable technical advance upon its predecessor and now comes the EM4 which has a performance in most respects comparable with its predecessor the EM3 but at approximately half the price.

Fig. 1. Close-up view of the control desk and camera of the Metrovick electron microscope Type EM4.

In general terms, the electron microscope is capable of a performance one hundred times better than that of the best optical microscope. In practical service in the laboratory it may be assumed that the EM4 enables detail twenty times finer than is observable by normal optical methods to be viewed and recorded. In the Metrovick microscope the final image is formed on a fluorescent screen viewed through a single port of wide aperture. The microscope design includes a camera fitting and no adjustment need be made to the normal viewing image.

Sharp definition on the fluorescent screen automatically means that sharp focus will be obtained on the photograph without further adjustment. Not only is the magnification of the EM4 far superior to that obtainable by normal optical methods, but the clarity of the definition is superior for the same magnification, as is seen in the two comparative examples of photomicrographs of diatoms (Fig. 2). It is possible, also, with the Metrovick instrument to produce stereomicrographs, the overall performance of the instrument having a resolution better than 100A.U. In all its constructional features as well as in its electronic design, the Metrovick EM4 is an outstanding instrument. Full technical details on application.

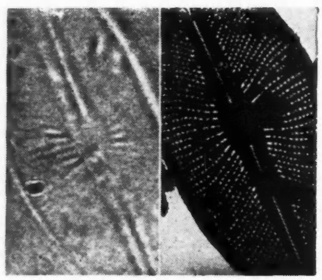


Fig. 2. In these photomicrographs of diatoms the clarity of definition obtainable with the electron microscope is shown by the right-hand photograph. The picture on the left shows definition obtainable with optical instrument under the same conditions.

DISCOVERY

THE MAGAZINE OF SCIENTIFIC PROGRESS

November, 1952 Vol. XIII. No. 11

Editor: WILLIAM E. DICK, B.Sc., F.L.S.
Editorial Office: 244 High Holborn, W.C.1. Tel. Chancery 6518
Advertisement Office: Aldridge Press Ltd., 15 Charterhouse Street, London, E.C.1. Tel. Holborn 8655
All Subscriptions, Distribution, and Business Communications to Jarrold & Sons Ltd., Norwich. Tel. Norwich 25261

The Progress of Science

The Monte Bello Bomb

BRITAIN'S first atomic bomb was exploded at 1 a.m. British summer time on October 3. This test explosion took place in the Monte Bello Islands off the N.W. coast of Australia.

The first announcement of the explosion came from the Admiralty, and this was followed by a statement issued by the Minister of Supply in London, which could scarcely have been more terse and guarded. This was the statement:

"The atomic weapon having been successfully exploded, the immediate task of the expedition at Monte Bello is to assemble all the technical recordings and other data with a view to analysing the results of the test. It is hoped that Dr. Penney and Admiral Torlesse, who have been in charge of the expedition, will be able to return to London in about a fortnight to make their report. When this is received the Government will consider what further information can be made public. Meanwhile, no further details about the explosion will be issued."

A meagre amount of additional information reached the British press in time to appear in the papers of October 3, which made the explosion their main news story of the day. The extra details came from newspaper and agency reporters who saw the explosion from the Australian mainland some fifty miles away. The most interesting detail they recorded was the fact that the smoke from the explosion formed a cloud which rose in a ragged shape—wide at the base and quite unlike the familiar mushroom smoke of American atomic bombs.

Conclusions drawn from this difference were:

(*a*) The bomb exploded in a different way from U.S. bombs, the force of the explosion being concentrated near the ground instead of being so largely dissipated in the upper atmosphere; the effect might therefore be that its blast would be intense over a much bigger area of ground;

(*b*) The plutonium in the bomb had been detonated by some radically new mechanism.

The general feeling is that the test was not only a technical success, but also an impressive demonstration of good security arrangements. The blanket of secrecy which surrounded the test was indeed thicker than anything associated with previous atomic explosions organised by the U.S.A., with the exception of the first test in the New Mexican desert in July 1945.

The Prime Minister lost no time in sending a message of congratulation to Dr. W. G. Penney, who was in charge of the Monte Bello test. Others who had made outstanding contributions to the whole atomic enterprise which rendered the explosion of a plutonium bomb possible were similarly rewarded by Mr. Churchill—for example, Sir John Cockcroft, head of Harwell where the first British work on the preparation and extraction of plutonium was done, and Sir Christopher Hinton, Deputy Controller of Atomic Energy (Production) at the Ministry of Supply, whose team of scientists, designers and engineers were responsible for bringing plutonium into factory-scale production.

Many commentators on both sides of the Atlantic have expressed the view that the success of the test will persuade America to revive Anglo-American co-operation in matters of atomic weapon development which existed during the war. That co-operation ended soon after the war; the last recorded instance of Anglo-American collaboration in this field goes back to 1946, when Dr. Penney participated in the tests made at Bikini.

But a change in American law will be needed before information connected with atomic weapons can be exchanged between Britain and America, for such exchange is specifically forbidden by the 1951 amendment to the U.S. Atomic Energy Act (which became law in 1946). No change could be effected until after the U.S. Presidential Election. Expert opinion in the U.S.A. seems to be more favourable to a change than does popular opinion, which is still to be convinced that American secrets will be kept secret after they have been given to an allied power.

The latest report available when this note went to press claimed that Dr. Penney, after reporting in London on the results of the October test, would be flying back to Australia again and would be superintending the testing of a second atomic weapon in November. No official confirmation or denial followed this report, but it may

be noted that the official statement originally issued this summer implied that there would be more than one test explosion.

Britain's M.I.T.—
A New Creation or an Adaptation?

DURING all the recent discussions which have gone on about higher technological education in this country the name of the Massachusetts Institute of Technology has been brought in whenever it was required to reinforce the arguments for the foundation of an entirely new establishment. The constant reiteration has had the usual effect of turning an idea into a slogan. But somewhat surprisingly no very clear picture of the character and function of M.I.T. itself has been presented in all the arguments for and against the suggestion that Britain should have a comparable technological university.

At this stage those readers to whom M.I.T is little more than a name will find enlightenment in the article published this month in which P. V. Danckwerts gives his personal impressions as an Oxford-trained physical chemist who went through a graduate school at M.I.T. before becoming a Cambridge lecturer in chemical engineering. All that he says supports the view that caution is needed in taking M.I.T. as a model for the foundation of a new institution in this country. He stresses, too, the point which tends to be overlooked, that it would be impossible to create out of thin air an academic assembly nearly the size of Oxford or Cambridge University.

Lord Woolton has stated that the policy of the Government is to build up "at least one institution of university rank devoted predominantly to the teaching and the study of the various forms of technology". Many people concluded that he meant that an existing institution was to be built up into a technological university. In the discussion which started from that conclusion the favourites as potential candidates for such development have been London's Imperial College of Science and Technology, Manchester College of Technology, Glasgow's Royal Technical College, and Loughborough College.

Of these four institutions, the one which has most in common with M.I.T. is the Imperial College of Science and Technology. It is of university standing (being a college of London University), has departments of all the primary technologies and some of the secondary, and research schools of high standards and traditions. A point in its favour is its close proximity to the Science Library and the Science Museum, while there is space for further building.

The Manchester College of Technology is the faculty of technology in the University of Manchester. For some reason it does not enjoy the full prestige which its record has merited. The college awards degrees and carries out research work. The professorial chairs are concentrated in the University and financial control comes through the City Council instead of the University Grants Committee. The granting of direct university status with perhaps the incorporation of the Royal Technical College, Salford, might be the beginning of a building-up process here.

The Royal Technical College, Glasgow, awards associateships not degrees, and is controlled by the Glasgow Corporation. On its present site, expansion would be difficult, but independent status in association with the Royal Heriot-Watt College would give some basis for expansion. A new impetus to higher technology in what is a classical location for engineering development would be particularly welcome, especially in view of the expansion in the petroleum and chemical field at Grangemouth and in older established industries.

In a category somewhat different from these three institutions is Loughborough College. We mention it because there is a strong rumour that this is the institution which the Government plans to develop into a technological university. The rumour has gained substance from the fact that a great deal of reorganisation is already taking place at Loughborough College.

The Government has promised action leading to the provision of better facilities for higher technological education. Everyone concerned awaits with impatience the details of the plans now being worked out, the announcement of which will be very welcome after all the rumour and speculation which naturally grew up after the Government's guarded and vague statement in June 1952.

Virus Research: the Need for Human Experiments

ONE result of the second International Congress of Internal Medicine, held in London in September, was to suggest the very large scope which must exist for research on human virus infections of which the symptoms are mild. There was a discussion at the Congress on viruses that affect nerve cells, of which poliomyelitis is the best known —and far from mild in its symptoms, at least in acute cases. Professor J. R. Paul, of Yale University School of Medicine, attracted public attention by referring to the difficulty of producing effective vaccines against three different strains of the virus from experiments on mice and monkeys alone, and his suggestion that the real experiments would have to be on man. He spoke also of work, in the United States, still at a preliminary stage, on the use of passive immunity, produced by concentrated serum from recovered patients, to carry exposed individuals through a period of heavy exposure to infection, during which further active immunity might develop. Dr. W. Ritchie Russell, neurologist to the United Oxford Hospitals, made some biting comments on the need for controlled investigation of factors affecting treatment. He put forward the rather obvious suggestion that this could best be done at special centres in which patients were treated at all stages from acute infection to rehabilitation, instead of at fever hospital and orthopaedic centre as is now commonly done. But judging from the free discussion which followed, the main interest of those contributing from recent research was in the relatively obscure group of viruses known as the Coxsackie viruses. These are so called from the fact that they were first recovered from patients in the town of Coxsackie, in New York State, during a poliomyelitis epidemic in 1947. The principal speaker on these viruses was a woman, Dr. Herdis von Magnus, Director of the Poliomyelitis Research Laboratory at the Statens Seruminstitut, Copenhagen. As many as fifteen different strains are now recognised. Their chief common factor, apart from their small size (about 15–25 millimicrons), is that they are

Dr. W. G. Penney, in charge of Britain's first atomic-bomb tests, has been Chief Superintendent of Armament Research at the Ministry of Supply since 1947. A graduate of the Imperial College of Science and Technology, where he was assistant professor of mathematics, his war work took him to the atom-bomb laboratory at Los Alamos. He was the only British scientist to watch the third atom-bomb burst over Nagasaki. His contribution to the U.S. atom-bomb project won him the American Medal of Freedom.

capable of producing paralysis in baby mice. This, however, is more the result of the experimental method used in the discovery of the original strain than of any real degree of close resemblance, and Dr. von Magnus agreed with Dr. C. H. Andrewes of Britain's National Institute for Medical Research that they would probably have to be distributed among a number of groups of viruses. Historically, again, the first interest was in the results of mixed infections with poliomyelitis and Coxsackie viruses. But there is no real evidence that such an additional infection is important in affecting the severity of symptoms in poliomyelitis; and in discussion there was an obvious and increasing interest in a variety of mild infections, characterised by fever and often some degree of pain from muscles, thought to be due to Coxsackie viruses. What seems of interest is that these numerous and relatively mild viruses were only discovered as a result of work on poliomyelitis, and that the potential field for research on human viruses is being very rapidly enlarged. It may be expected that the Coxsackie viruses will remain obscure and difficult for a long time. But it by no means follows that they will be less profitable in the long run for study than poliomyelitis because less dramatic in their effects.

The most ambitious of the discussions at the Congress was on disturbances of fluid and electrolyte balance—or, in plain language, of water and salts. The importance of the relationship between the cell and the fluid medium in which it lives is self-evident to any student of biology, and there has been much research on the mechanisms by which fluid balance is controlled, and the effects of disturbing factors. What was of interest at the Congress was the extent of attention to the subject which is being paid by senior physicians in many countries (more than thirty were represented), and the variety of conditions in which information of medical usefulness can be obtained. Those mentioned included diseases of the liver and kidneys, treatments involving the adrenocortical hormones, diabetes, under-nutrition, haemorrhage, severe burns and conditions involving shock. The list is the more impressive that a number of other but related problems including tropical adaptation were excluded from discussion.

A similarly broad approach was shown in a further discussion on antibiotics. Of particular interest as a bridge between experimental biochemistry and medicine was a review by Professor A. Kekwick (London) of the distribution and behaviour in the body of those most commonly employed—penicillin, streptomycin, aureomycin, chloramphenicol (chloromycetin) and terramycin. This is mainly at the fact-finding stage at the present time, with the explanation of differences mainly tentative. An example of practical interest is the extent to which the blood-brain barrier is penetrated. Penicillin hardly penetrates at all except with very much higher and more prolonged doses than are normally used, and neither penicillin nor terramycin are found significantly in the cerebrospinal fluid. Streptomycin, on the other hand, within a few hours, gives a concentration from one-fifth to one-tenth of that in the blood plasma; aureomycin from one-half to one-fifth after several days' delay; and chloramphenicol from one-third to three-quarters very rapidly. In this and other locations, there are obvious problems for research in the extent and speed of penetration of particular antibiotics; as also in the means by which penicillin, in conjunction with a second antibiotic, can contribute to a combined effect on bacteria, against which penicillin by itself is either not effective or only slightly so.

Fuel and Power Policy

In 1951 the Minister of Fuel and Power appointed a committee, under the chairmanship of Lord Ridley, to consider the steps required to promote the best use of fuel and power resources. The committee's labours have resulted in a report (Cmd. 8647, H.M.S.O., 6*s*. 6*d*.) which in a harder-hitting and more classical age might have been dismissed with "*Parturiunt montes* . . .", or the proverb might have been inverted to say that the mice had laboured and produced a ridiculous mountain.

It is difficult to find in the 240 pages of the report the positive recommendations which would be hoped to give some encouragement that the problems had been defined and prescribed for. A mass of evidence from Gas, Electricity and Coal Boards is presented, most of it conflicting and with little attempt on the part of the committee to reconcile it.

The following points which have been raised in previous issues of DISCOVERY receive backing. Electric fires can be justified for ease of switching on and off and in providing for intermittent needs. Improved efficiency of burning

solid fuel for room heating can be expected to give increased comfort rather than economy. Alternatives to steam traction for locomotives should be more rapidly developed. District heating schemes have not yet been demonstrated to be economic. Miners' concessionary coal should be reduced by financial compensation and improved appliances in miners' homes. The development of nuclear energy, tidal power and heat pumps cannot be looked to for relief in the near future.

Many pages of the report are devoted to an argument about the use of price mechanism as a means of bringing about coal-savings. The argument may be valuable as an exercise in theoretical economics, but it did not lead to any useful conclusion; in fact, it divided the committee into two exactly equal and irreconcilable camps. The idea as advanced by the committee's economists is that there is no immediate prospect of the pre-war situation returning in which there was abundant cheap coal for all needs; to get a stable balance between coal output and coal requirements for home consumption and export, home consumption must be checked by economy in the use of fuel. This economy would follow, so the argument runs, if the price of coal was increased. The economists argued, moreover, that by so doing a price more realistically related to the cost of production would result; they thought the present price was about £1 a ton too low. The rest of the committee disagreed absolutely with these contentions; the suggestion that an excise levy of £1 should be added to the price of every ton of coal they rejected as a factor that would make for inflation.

But none of the committee grappled with the central unresolved problem: how to obtain any real cost comparisons in an economic set-up which is largely managed and monopolistic. In a free competitive system, the raising of price could be expected to result in the attraction of capital to develop more marginal output. With nationalised coal, electricity and gas, the monopoly basis makes valid cost comparisons almost impossible. Any investigation which does not realise this is debarred at the outset from coming to any effective conclusions.

Two final recommendations of the report may focus further attention on these problems. No. 39 reads, "The Minister of Fuel and Power should be assisted in his general control over the price policies of the nationalised fuel and power industries by the establishment of a specialised Tariffs Advisory Committee." No. 40 reads, "The Ministry of Fuel and Power should establish a Joint Fuel and Power Planning Board."

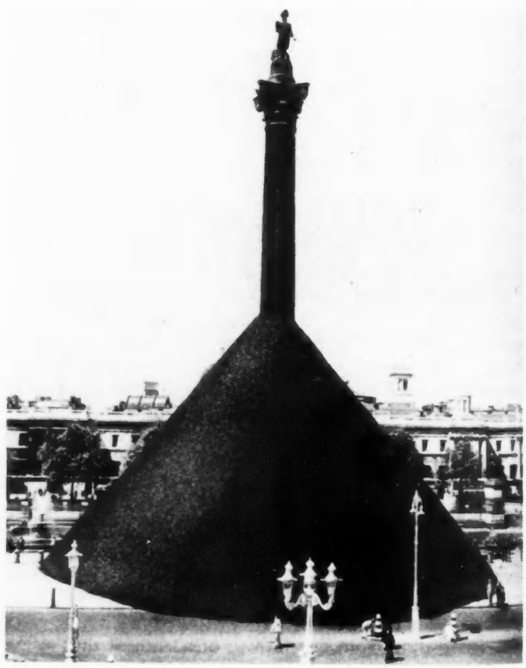
It is difficult to avoid concluding that some more decided report would have come from a committee with more technical representation. Only one engineer, Sir Claude Gibb, served on the committee.

The method of composing Government committees almost exclusively of economists, lawyers and trade union leaders is not always the best where highly technical questions are involved. They may be excellent where some types of evidence are involved which can be weighed with judicial wisdom and political flair. What is wanted is probably unobtainable in this country, a committee mainly of leading businessmen who have been university-trained in science or engineering. They seem to come that way in large numbers only in the United States.

Less Smoke, More Heat

THE problem of 'atmospheric pollution' is more or less entirely concerned with the noxious results which come from burning raw coal on a large scale. There can, of course, be in addition some pollution of the air by the effluent gases and vapours from chemical works, but on the whole the chemical industry controls the discharge of volatile effluent very efficiently and the prominence which is given to the cases of negligence or failure in this respect is a measure of their rareness. Such cases only affect small areas, and for Britain as a whole it is the pollution produced by coal burning that is most serious and most demands attention. A comprehensive monograph which devotes nearly all its pages to this most important type of pollution has just been published—*Atmospheric Pollution: Its Origins and Prevention* by Dr. A. R. Meetham (London, Pergamon Press, 1952, 268 pp., 35*s*.)—and should win favour with all those whose professional activities bring them into touch with the practical aspects of atmospheric pollution and its control.

The smoke which domestic coal fires generate has long been recognised as an evil which ought to be abolished from our cities; in fact, this recognition came almost as soon as large-scale coal burning started. It was in the thirteenth century that the inhabitants of London, for example, took to using coal to warm their houses, and its introduction for this purpose was very speedily followed by an Act of Parliament prohibiting the burning of coal in the



A vivid impression of the extent of atmospheric pollution occurring in British cities is given by this picture showing what a month's fall of soot in the County of London (area about 120 square miles) would look like if swept up into a pile in Trafalgar Square.
(*Courtesy, National Smoke Abatement Society*.)

TABLE 1

POLLUTION EMITTED FROM COAL IN GREAT BRITAIN
MILLION TONS PER YEAR

	Coal used	*Smoke*	*Ash*	*Sulphur dioxide*	*HCl and other chlorides*
Domestic purposes: fires .. 45; gas and electricity 20	65	1·2	0·2	1·5	0·1
Industrial boilers	65	0·9	0·3	2·1	0·2
Other industrial uses	50	0·3	0·1	1·6	0·2
Total	180	2·4	0·6	5·2	0·5

capital! This piece of smoke-abatement legislation was initially most energetically enforced, but sheer necessity imposed by the dearth of firewood rendered ineffective the laudable efforts of those who wished to ban by law the smoke pall from our cities. Coal steadily supplanted wood in the home, the amount burnt in domestic fuel increased as the population increased and the smoke clouds grew accordingly. The extent of atmospheric pollution increased tremendously when the Industrial Revolution got into its stride.

The 'smoke-abatement' campaign is a relatively modern crusade. In the old days atmospheric pollution was more or less accepted as a necessary evil inseparable from industrial activity; it is comparatively recently that smoke abatement came to be recognised as something that was not only desirable but also technically feasible. The crusaders are now looking forward to a smokeless future—"just as we no longer throw rubbish into the street, we shall eventually cease to discharge smoke into the air", says Dr. Meetham. But this prospect is not just round the corner; it represents an objective which cannot speedily be reached, for it calls for the replacement of all inefficient coal-burning appliances, both domestic and industrial, which can only be achieved over a number of years.

Dr. Meetham quotes some actual figures for the amount of pollution due to the three major classes of coal users, which are shown in Table 1. (It should be noted that this table couples the pollution arising in the production of gas and electricity used in homes with that caused by domestic fires; this is convenient statistically, but should not be allowed to divert attention from the fact that industrial coal burning—including that of the gas and electricity industries—accounts for more than half of Britain's atmospheric pollution.)

The *smoke fraction* in the table is familiar enough. This consists of fine carbon mixed with tarry hydrocarbons, which settle sooner or later as soot. An important point about it is that because of the small size of the particles (the average diameter of which is around three-millionths of an inch), it behaves in many respects like a gas and has similar powers of penetration. It will travel more or less anywhere that air can go; with the result that the householder who instals perfect equipment that generates no smoke at all may nevertheless find his house invaded by the smoke from neighbouring chimneys.

The *ash* particles are far larger than the smoke particles. Comparatively few such particles escape from domestic chimneys, as the air flow in the flues is not fast enough to lift them; most of the ash in a domestic fire does in fact collect in the grate. With factory chimneys, the flue gases move much faster, and carry particles up to a tenth of an inch in diameter out into the atmosphere. These large particles settle quite rapidly (the largest are airborne for only five seconds or so), with the result that the nearby streets collect most of the ash from a factory chimney. According to Dr. Meetham, ash which pollutes the atmosphere comes mainly from industrial sources; he estimates that four-fifths of it is industrial, as against one-fifth from domestic fires.

The *sulphur dioxide*, which accounts for 5·2 million tons of the total amount (8·7 million tons) of polluting materials shown in the table, is most damaging, as it corrodes a great many materials ranging from building stones to household fabrics. This corrosive effect seems to be mainly attributable to the sulphuric acid into which sulphur dioxide is readily converted.

What can be done to prevent pollution? Dr. Meetham states the categories of appliances which inevitably create smoke if they are run on raw coal; domestic fires he mentions first, followed by small vertical boilers, locomotives and most existing types of heat-treatment furnaces used in the metallurgical industries. The logical conclusion of this statement is that domestic coal fires must go, to be replaced by gas fires, or fires using coke or smokeless fuel of the 'Coalite' type; railways would run on electricity, though Dr. Meetham does not bar diesel-driven locomotives or oil-fired steam engines. In other words coal burning is a procedure to be restricted to industrial installations. Here Dr. Meetham is most optimistic, evidently having great faith that the desire for efficient operation of large plant will lead to the most efficient combustion of coal. One feels that there is some justification for a large part of his optimism, though efficient coal utilisation will still leave the problem of coping with the most noxious chemical in the atmosphere—sulphur dioxide. This can be removed from flue gases (this has been done effectively at Battersea Power Station, for instance), but only at a high cost; there seems to be plenty of room for more research and development work aimed at the perfecting of a cheap method of removing sulphur from the waste gases from coal-fired plants.

Prof. Kapp was Professor of Electrical Engineering at London's University College from 1935 to 1950, and for part of the time he was Dean of the Faculty of Engineering. In this article he considers the scope of the operations performed by electronic calculating machines and comes to the conclusion that this stops far short of anything comparable to 'thought'.

What Do Electronic Computors Prove?

Prof. REGINALD O. KAPP, B.Sc., M.I.E.E.

THOSE remarkable calculating machines that are sometimes referred to as electronic brains, but whose formal title is electronic digital computors, have captured the popular imagination; but not because of their usefulness to the mathematician nor because of the many ingenious engineering principles embodied in their construction. The layman would only be bored by a description of their highly complicated mechanisms and other technical details. He does not really want to know how they do their job nor about the kind of mathematical problem for which their use is economical. What fascinates him are the claims and suggestions that are being made about them in broadcasts and popular articles in the Press.

These talks and articles are suggesting that electronic computors are in some fundamental way different from all other existing types of machinery in that they can do things of which hitherto the human mind alone was thought to be capable; and that they may be instrumental in solving one of the great problems that for centuries has baffled philosophers and scientists—that of the relationship between mind and body. The layman is left with the impression that they will provide the answer to some question in which he, just as much as the mathematician and the engineer, is interested and concerned: something of deep philosophical import.

Several other electronically operated devices share with the computors this aura of fascination and mystery for the layman, and are being made the subject of similar far-reaching claims. There are, for instance, those little battery-driven trucks covered with casings like the shells of tortoises. They are equipped with electronic relays, which connect the coverings with the driving gear. The trucks change direction as soon as they touch, suggesting (to anyone unfamiliar with the mechanism) that they are aware of each other's proximity. It is being said that these contribute in some way to research into how the central nervous system of the higher vertebrates works.

There are also machines that play noughts and crosses and never lose. One ingenious mathematician has worked out the best response to every possible move of his opponent, and the machine is fitted with switching devices so arranged that any move of the human player automatically sets the switches so that the machine shows this best response.

Again, machines to play a simple end-game of chess have been constructed on a similar principle, and in theory could be made to play a complete game. But the preliminary work of selecting the best possible response at every stage of the game would be great indeed, even if performed with the aid of some calculating machine. There are no less that twenty possible opening moves and an even wider range at later stages of the game. Every possible alternative would have to be allowed for. Nevertheless if the feat were accomplished, these machines would give every appearance of doing some powerful thinking—most fascinating and mystifying to anyone who did not know that all the thinking had been done beforehand by the designer.

There is the crux of the matter. The public is being led to believe that it *is* the machine that is doing the thinking; and so it concludes, reasonably enough, that the invention has an epoch-making significance. If it can solve mathematical problems beyond the power of the human brain, play games normally requiring a high degree of intellectual power, it is not difficult for those who are not engineers to persuade themselves that this new invention does throw important light on the relation between mind and body.

The notion of the automaton—a machine produced in a scientist's laboratory and capable of human behaviour—has always been a popular figure in imaginative fiction, and the world's literature contains many such. There is the homunculus that Goethe's Faust contrived. There are the robots in the play by the brothers Capek; they eventually revolted against the human race. There are the man and woman that resulted from the experimenting by the super-beings in Shaw's *Back to Methuselah*, who had quickly to be destroyed because of their unseemly quarrelling. There is the beautiful statue made by the sculptor Pygmalion, which became a living woman. There is the monster Frankenstein, who destroyed his creator.

Whether such fantastic creatures serve the purpose of pure entertainment only, or are employed for a purpose in a story with a moral, they appeal to the adolescent in every one of us. And so what the layman is being told about electronic computors pleases him. He feels free to think that there may, after all, be something in the notion that a synthetic human being will some day be constructed. If a machine can be built to accomplish one of the most difficult tasks of which the human brain is capable—the solving of those mysterious things called differential equations—the layman can hardly fail to conclude that it should be quite easy to construct a machine to perform all the ordinary tasks that the common man has to do every day. Such daydreams are not new. What is new is that scientists, from whom we expect fact and not fiction, should encourage them.

The wonder, and even awe, with which these electronic computors, toy tortoises, mechanical players of games and so on are regarded would, I feel sure, diminish, if it were realised that similar claims could, with as much justification, be made for quite a number of other established mechanical devices. For instance, the selective-protective gear that is installed on electrical networks for the purpose of isolating faulty sections has to be so highly discriminating that it gives the impression of almost 'thinking'. In all

circumstances the number of switches that open must be the minimum necessary to isolate the fault; all others must continue in service. The gear behaves as though it were aware of the location of the fault and of the proper way of clearing it, just as the toy tortoises behave as though they were aware of the proximity of other toy tortoises. But even more remarkably, the protective gear not only discriminates between faults in different sections of the network, but also between different *kinds* of faults. It can even be designed to test for the *nature* of the fault.

Some faults are quite transient, and it would be safe to reclose the switches a moment after they have been opened. The gear does this, perhaps two or three times, and leaves the switches permanently open only after repeated trials have proved it necessary. It will be seen then that in this selective-protective gear are to be found all the features that, in electronic computors, have led a few distinguished scientists to the conclusion that they 'think'.

Then there is automatic boiler-house control equipment. This gear ensures that for all operating conditions of large boilers the right quantities of coal, water, forced and induced draught air shall be supplied. It might be said by enthusiasts to behave like an animal that knows instinctively what balanced diet is good for it. And if something simpler is preferred, why not the gear that operates traffic lights? These lights could, with the same justification, be said to behave as though they were aware of oncoming vehicles. And if these devices are not sufficiently accessible, the neurological research workers might study instead the electric fuses in their own homes. These could be regarded as behaving as though they were aware that the wires were short-circuited.

In putting these ideas forward I am quite serious. I do not want to suggest that nothing whatever of general significance can be inferred from the behaviour of toy tortoises, electronic computors and electronic players of games. What I do want to suggest is that they have no greater significance than various other contraptions devised by man; so why should they, rather than selective-protective gear or automatic boiler-house control systems, be seized on as subjects for philosophical speculation and neurological research?

The devices that play noughts and crosses do not do any thinking, as I have already explained; the responses have all been thought out beforehand. Nor does the automatic chess-player. The way it shall scan the board has been determined by the operator who made the preliminary adjustments. Similarly, in spite of deceptive appearances, selective-protective gear does not decide when to cause certain switches to open, nor how to test for a fault; the conditions under which this is to happen have been decided by the engineer who made the various settings. And it is the control staff of the boiler-house, not the automatic control equipment itself, that thinks out how much water, coal and air is needed by the boiler for each particular working condition, and that sets the various controls accordingly. And a fuse, of course, does not decide at what current to blow. This decision is taken by the person who inserts a fuse wire of appropriate thickness.

Those who attribute a philosophical significance to the performance of electronic computors are, no doubt, aware of all this. I have never heard anyone say that a fuse thinks. If he did, few people would believe him; one knows too much about the way a fuse does its job to be so easily deceived. But electronic computors are mysterious things, and so it is easier to persuade oneself that they can help to solve mysteries such as that of the mind-brain relation.

This process of self-deception has been encouraged by the anthropomorphic terms that have been applied to electronic computors. The various adjustments that have to be made when preparing the apparatus for a given service are called 'instructions', although equivalent adjustments for selective-protective gear or boiler-house control equipment are called by the more conventional engineering term of 'settings'. This change in terminology subtly suggests that the computor has a capacity for comprehension and learning not possessed by other man-made machines.

The output of these machines is, moreover, referred to as 'information', a term again suggesting that the machine is endowed with that capacity of the human mind that is used in dispensing information. Terms more often used by engineers are 'indication' or 'record' or 'reading'. An engineer says that boiler-house control instruments or selective relays give an 'indication' of what is happening, and a 'record' of what has happened. Nothing anthropomorphic is implied by these terms; realism is maintained.

Another phrase, used to indicate the notation used for numerals, is 'machine language'; and the term 'decision' is used in connexion with the sequence of operations for which the machine is adjusted. The suggestion conveyed by these terms—that the machine has the accomplishment of a foreign language and the capacity for taking decisions—has done much to foster the false notion that, unlike any other mechanisms, these electronic devices have a philosophical significance.

Use of the word 'memory' has the same effect. It is necessary at times for some figures to be stored in the machine while other operations are proceeding. This may be effected by an accumulation of electric charges in a capacitor. A similar store of charges is sometimes used to ensure that traffic lights do not change until a predetermined number of vehicles has passed the pads. One does not say that the traffic lights have a 'memory', and so no one is inclined to attribute human accomplishments to them. But the word is (unfortunately, I think) used for digital electronic computors; and the inevitable false conclusions have not been long to follow.

Biologists warn us against the danger of being anthropomorphic about animals—of attributing their behaviour to the same kind of impulse or motive that we ourselves, as human beings, experience. Many would deprecate it if one were to say that a bird, following its nest-building instinct, reached a 'decision' to use one twig rather than another; or that the fledglings were 'instructed' to leave the nest. Perhaps they may be over-cautious in so deprecating, but I am sure it is only being realistic to deprecate the highly anthropomorphic terms in which digital electronic computors are being discussed nowadays. Anyone who would hesitate to suggest that a bird thinks should hesitate a hundred times before suggesting that an electronic computor does so. It is sometimes asserted that one cannot make any significant distinction between living and lifeless mechanisms. I need not discuss here whether this assertion can be justified or not. But I am quite sure that one cannot

"The electronic computor is only a super abacus." An engineer checks the wiring behind the machine known as IBM Electronic Selective Sequence Machine.

make any significant distinction of the type now being attempted between electronic computors and other non-living mechanisms.

No one would try to do so if it were better appreciated that these devices are no more than elaborations of a simple aid to arithmetic that has been in use for many centuries—the abacus. This device consists of a frame equipped with a number of horizontal wires, each carrying ten beads threaded along it. By supposing each bead on the top wire to represent a unit, each on the second wire ten units, each on the third a hundred, and so on, arithmetical calculations can be performed. Movement of beads from one side of the frame to the other can represent addition. When a batch of beads is left at one end while another operation is proceeding, a number is being stored. In the terminology of electronic computors, the abacus would be said to 'remember' the number.

When beads are replaced by very much more mobile electrons, and the straight wires by highly complex conducting circuits, one has a device in which numbers can be added in a minute fraction of a second and in the most elaborate groupings. But in essence the electronic computor is only a super abacus. As such it is one of the many tools that man, the tool-using animal, has devised to save himself labour and to help him master the forces of nature.

The naïve notion that this, or any other of the devices mentioned, has philosophical implications would not be entertained so readily if the basic question to which these devices are said to provide the answer were more carefully formulated. Let me now attempt to formulate that question. It is really quite a simple one: Is the brain the originator and director of purposeful mental activity, or is it just an instrument by means of which a non-material mind acts?

Among the things that we include in the term mental activity are thoughts, wishes, illusions, decisions, memories, control of our movements. Do these, the question is, originate in the brain or elsewhere? Schools of philosophy are sharply divided on the point, though all readily admit the importance of the brain in the control of our movements. Let me mention, in turn, the implications of each of these contrasted views.

If the brain is an originator one can make no significant distinction between the terms 'mind' and 'brain'. The origin of thought and the control of our movements are in that physiological organ, and it is rather better to say that we think with our brains than that we think with our minds. This is the more materialistic of the two opposed views, for it attributes the origin of thought and control to a material system—the brain. If this view is correct the brain is in a quite fundamental way different from electronic digital computors, boiler-house control equipments, fuses, traffic signals and all other known man-made devices. For these are all, without any doubt whatever, not originators.

If, on the other hand, the brain is an instrument and not an originator one must conclude that the originator of thoughts and control of our movements (which we do after all observe) is something else, something called mind. If this is the correct view, one must make a significant distinction between brain and mind; it is then correct to say that we think with our minds and incorrect to say that we think with our brains. The brain is regarded as the device that serves to make our thoughts effective. This is the more idealistic of the two opposed views; it implies that the mind is a real and also a non-material influence. Those who hold this view must also believe that the brain is fundamentally similar to electronic digital computors and all the other instruments by means of which human thought is made effective and man achieves control over material circumstances.

Thus those who take the more materialistic of the two views would, if they thought the matter out logically, insist on the fundamental distinction between the human brain and an electronic digital computor; they would make every effort to prove that the brain is an altogether unique kind of system, not, like other devices, an instrument of thought, but unlike them, an originator. And, conversely, those who take the more idealistic view and say that the mind is distinct from the brain should also insist that no fundamental distinction can be made between one instrument of thought and another; they should regard the brain as being in the same category as electronic digital computors and other machines.

But both sides always seem to argue exactly the other way about. Which only shows how little disciplined and logical thinking is brought to this important subject.

The Invention of Scientific Explanation

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THE power of science is the power which derives from the success of a method of answering certain kinds of question. Questions that cannot be answered by the method are usually avoided in scientific work, though that does not mean that they are uninteresting or unimportant; some of them are from many points of view the most interesting and important questions a human being can ask. Several attempts have been made in the last three hundred years and more to define scientific method. None has satisfied everyone, and perhaps the methods science uses will always elude satisfactory definition, because as long as science progresses they are always developing. Nevertheless, there are certain characteristics common to the procedures used in most modern sciences and, at the risk of gross over-simplification, modern scientific method can be sketched in terms of these.

The first thing to be noticed is that a scientific inquiry always begins with a problem. It is not the slightest use making observations, and collecting facts, except in relation to some problem, in answer to some question. The number of facts in the universe is infinite; a random observer gets nowhere.

Consider the problem of heredity. This is one of the oldest phenomena in which human beings have been interested, and for centuries before Mendel breeders and hybridisers of plants and animals had collected and classified a large amount of empirical information about it. Various theories of heredity had been put forward, but none was satisfactory either as an explanation or as a guide to research. Mendel pointed out that the problem had not been formulated precisely enough. He began by breaking down the general problem of heredity into a number of precise questions. He saw that it was necessary to discover the number of different kinds of offspring produced by hybrids, and their numerical ratios in different generations. He chose for his investigations a convenient plant, the garden pea, and concentrated on specific characters, for example the colour of the cotyledons, which in the seeds of some plants were yellow and in others green. He selected for study seven such pairs of clearly distinguished characters, and paid no attention to any other character. He bred pure lines, and by crossing these under controlled conditions he obtained the accurate information which he generalised into his well-known statement of the ratios found in different generations. For example, hybrids obtained by crossing two pure lines, one with yellow seeds and the other with green seeds, all had yellow seeds. These hybrids themselves produced offspring in the ratio: 3 with yellow seeds: 1 with green seeds. In some other species of plants Mendel had found hybrids with intermediate characters. Since no intermediate colours appeared in the seeds of the pea, he suspected that some of the offspring with yellow seeds were hybrids; he said that yellow was 'dominant' to green, suppressing it in the hybrid. Further breeding experiments showed that the ratio 3 : 1 was in fact composed of 1 pure yellow: 2 hybrids: 1 pure green. The six other pairs of differentiating characters gave the same ratio as this first pair. He went on to investigate the ratios found between members of more than one pair of characters.

These ratios Mendel discovered simply by the inductive procedure of collecting and classifying data in answer to precise questions, using controlled experiments to isolate the different variables present. This inductive procedure plays an important part in all scientific research. Mendel's next step involved mental operations of a very different sort. On the basis of his inductive generalisation he put forward a bold, abstract theory. He supposed that each character was determined by a pair of factors (now called genes), one member of the pair being carried by the egg and the other by the pollen cell. By defining the conditions under which egg and pollen cells were produced and could unite, and by using his concept of dominance, he constructed a theory from which he could deduce all the ratios so far obtained.

It is important to notice that Mendel did not and could not argue from his ratios to this theory by a continuous logical sequence. Reflecting on the ratios and on what he knew about fertilisation, the theory came to him by an act of scientific imagination. Of all the gifts that make an original scientist, this is undoubtedly the greatest; and at this point, where the scientist, no less than the artist and the poet, enters upon an act of imaginative creation, he finds himself beyond the aid of method. The next step taken by Mendel shows where method once more comes into play. He tested his theory by deducing from it further consequences, which he examined experimentally. Mendel's work changed the study of heredity from a form of empirical technology into a science consisting of a body of precise theory giving direction to controlled experiments.

The object of the method sketched by means of this example is to find an explanation of an observed phenomenon or regularity, and it implies a definite conception of explanation. A regularity, for instance Mendel's ratios, is said to be explained when the statement describing it can be deduced from a more general set of statements constituting a theory. "Regularity A (e.g. the ratio 3 : 1) is explained by theory B (e.g. the theory of genes)", means "The statement describing regularity A is the logical consequence of theory B." In the early stages of an inquiry, the most prominent part may be played by the inductive procedure of collecting and classifying the data to define the regularities present, the use of a series of controlled experiments making it possible to deal with a problem involving many variables. In a well-developed science, research is largely given direction by the theories in use, and consists of attempting to extend their range by making deductions from them, testing these experimentally, and modifying, rejecting, or replacing the theories when they fail. The general result is that statements and theories covering a small range of facts become replaced by, or incorporated into, more general ones, so that a single system of logically connected doctrine is built up, giving explanations of a whole range of phenomena like those explained by modern electro-magnetic theory, quantum theory, or genetics.

THIS is the first of a series of four articles on the development of method in Western science. The first article is concerned with the steps leading up to the formulation by the Greeks of the conception of scientific explanation on which the whole of Western science is based. With this conception science, as distinct from technology, began. The three articles that follow will deal with the stages by which modern scientific method was developed by the introduction of increasingly powerful and accurate procedures for constructing and testing theories, and by the adaptation of the Greek conception of explanation to fresh types of problem. The first advance on the Greek deductive method was the development, beginning in the later Middle Ages, of modern methods of induction and controlled experiment. This will be the subject of the second article. The third article will describe the creation of an entirely new mathematical science of dynamics, completed by Newton in the seventeenth century, to explain the phenomena of motion. The fourth article will discuss the procedures adopted, in the eighteenth and nineteenth centuries, to give a scientific explanation of the origin and development of organic forms, leading to the formulation of the modern theory of evolution.

The main conclusion following from the study of the history of science from the point of view taken in these articles is that the great revolutions in science are revolutions of the intellect and of the imagination; the mere accumulation of observational data, though indispensable, is secondary to the acts of mental creation that show how to exploit the data of the natural world in a new way. The richness and strength of the Western scientific tradition, its power both to enlighten and to control, is the product of the succession of such acts that it has seen: new questions have led to new types of hypothesis, to new logical and mathematical procedures for constructing and criticising hypotheses, to new scientific apparatus for testing them experimentally and extending their range.

Like most people working in an established tradition, modern scientists, and the public which reads of their activities, are apt to take present methods of scientific thought and procedure for granted. These methods are in fact the product of a long history of intellectual effort. Records show that before there was anything consciously recognised as science, the earliest known peoples collected observations about phenomena of practical interest in everyday life, developed in some parts of the world remarkable technologies, and made hypotheses about the universe and its origins. The first conscious conception of science seems to have been made by the Greeks. Their claim to be called the founders of the Western scientific tradition is that they were the first to ask: What is scientific explanation? and to formulate a programme on the basis of their answer. The conception of scientific explanation they reached crystallised from their study of deductive geometry, a science which they invented and which they took as the model for all their scientific research. The Greek conception of scientific explanation has shaped the whole history of Western science, and is still held.

Technology and Myths in Ancient Mesopotamia and Egypt

Before the Greeks invented science, peoples in the four most ancient known centres of civilisation developed a considerable competence in basic technology. Two of these peoples, those of the rivers Tigris and Euphrates, and of the Nile, the Greeks knew and regarded as their masters in technology; the other two, established on the Indus and on the Yellow River in China, remained isolated from the West too late to come into this story.

The technology of ancient Babylonia and Egypt, of which the earliest records date from about 3500 B.C., was a collection of particular practices without any general conception of scientific explanation or of scientific method. Interest was confined to finding solutions of individual problems as they presented themselves. Further questions, leading to a general conception of natural causation and to a general use of science to make sense of the world, remained unasked. The gap was filled by religious myths, especially some giving an account of universal origins.

As a basis for science, two achievements of the technology of the ancient Babylonians and Egyptians are of outstanding importance. First, they learnt how to handle and use certain natural materials: metals, dyes, drugs and, in their surgery, living tissues; they learnt to grow different crops and to husband animals, to transport heavy weights, to build, and to control water by means of canals. Secondly, they invented writing and mathematics, abstract systems for organising and communicating information. Their mathematics was developed entirely as a means of solving certain practical problems, and their method of using it illustrates very clearly the essentially pre-scientific, technological character of their approach.

The Babylonians especially became extremely skilful in arithmetical computation, the earliest known texts, cuneiform impressions made with a stylus upon clay tablets, dating from about 1700 B.C. They used a system of counting both by tens and by sixes, the latter surviving in modern methods of measuring angles and time. With the symbols ∇ (for $\frac{1}{60}$, 1, 60, 60^2 etc.) and < (for 10), they could write any number by making the value of a symbol depend on its position. Thus, 1, 2, 3, 10, 11, 20 were written ∇, ∇∇, ∇∇∇, <, <∇, <<. On reaching 60 they began again with ∇; then 70 was ∇< (60 + 10), and 120 was ∇∇. The sequence ∇∇∇ <∇∇ ∇ would mean $3 \times 60^2 + 12 \times 60 + 1$, that is 11521. At some unknown date the Babylonians introduced a special symbol for zero, thus avoiding the ambiguities possible in their original system as to the absolute value of a number. Their notation was not equalled in the West until the Arabs introduced the modern system of positional notation from India.

The practical use of Babylonian arithmetic was to deal with problems of inheritance, division of land, compound interest, the digging of canals, astronomy and other economic and technical matters. To solve these they made

multiplication tables and tables of reciprocals, of squares and square roots, of cubes and cube roots, and of exponential functions; they had a formula expressing the so-called 'theorem of Pythagoras'. Texts by teachers in schools for scribes show that they clearly understood the use of a general formula for solving different problems. For example they set up problems about the wages to be paid for labour according to a given amount per man per day, and taught their pupils to solve them by a method amounting to solving quadratic equations. They had a method for calculating the area of a circle from its circumference. But they never generalised these methods by using an algebraic notation; they based them simply upon the tabulation of results obtained by trial. They showed no grasp of anything amounting to a general proof.

This restriction of their methods of providing solutions of particular, practical problems is characteristic of all the scientific work of the Babylonians and Egyptians. It is shown very clearly in Babylonian astronomy, the most remarkable achievement of ancient technology. Beginning about 1800 B.C., Babylonian astronomers accumulated a large amount of information about the movements of the sun, moon and planets. They developed a complete mastery of arithmetical methods for describing their observations, of cardinal importance being the use of arithmetical progressions to describe the irregular movements of the planets through the fixed stars. In the Assyrian period, during the last five centuries B.C., and especially during the last three centuries B.C., their theories, in point of mathematical character and accuracy, became fully comparable with the contemporary geometrical theories of the Greeks. But whereas the Greek astronomers all assumed a geometrical moving model for the universe, and tried to deduce the observed motions from that, there is no trace in Babylonian astronomy of any kind of mechanical model. Babylonian astronomical theory remained purely a method of computation; it invited no speculations about the dynamics of the heavenly bodies, still less did it suggest any general conception of natural causation. The Babylonians were interested in astronomy only as a technique for the immediate purposes of making a calendar and casting horoscopes. The same is true of the Egyptians. The measure of the Babylonian and Egyptian achievement in astronomy is that their work became the basis of all later calendars; but it never became an instrument for theoretical speculation and criticism, an instrument with which to fashion a scientific cosmology. The question simply did not arise for them.

In so far as the Babylonians and Egyptians ever offered general explanations of events, it was in terms of myths describing the activities of gods. Thus the Babylonians attributed rain to the intervention of a great bird, Imdugud, who "covered the sky with the black storm clouds of its wings and devoured the Bull of Heaven, whose hot breath had scorched their crops"; the Egyptians said that in an eclipse a giant hippopotamus was eating the moon.

Some of the most illuminating examples of this type of explanation are the myths of the origin of the universe. These are found in Mesopotamian and in Egyptian writings, and fresh versions were produced by the Greeks. Events in the different myths follow a broadly common pattern: the story relates how a god, a superhuman being, fashioned the parts of the universe, usually from a formless chaos of undifferentiated matter, and set each part in its place and order. A good example is the Babylonian myth, *Enuma Elish*, with the Babylonian god, Marduk, as its hero. This version dates from about 2000 B.C. but is apparently based on a much earlier version with Enlil, the god of Nippur, in the principal part; in a later version, written after Assyria had become the dominant political power, Ashur replaces Marduk.

Enuma Elish begins with an account of the earliest stage of the universe as a large, undifferentiated mass of water and mist mingled together. In the midst of this watery chaos appears a pair of gods, who give birth to other pairs, these to yet others, and so on, each pair personifying a natural power or substance. The gods bring into the universe a new principle of activity, and they come into conflict with inert chaos. The climax of the myth is the victory of Marduk, emerging as supreme ruler of the gods, over the goddess of chaos, Tiâmat, after which he proceeds to set the universe in order. Dividing the body of chaos in two, he separates the sky from the earth and sea. He then organises the calendar, setting on the sky he has fashioned the constellations whose risings and settings determine the years, months and days. In their places he arranges the planets, the milky way, the zenith, the moon (to measure time), and so on, each entity receiving its commands. Eventually Marduk creates man, to relieve the gods of the drudgery of work.

FIG. 1.—Marduk destroying Tiamat, goddess of chaos, shown in the form of a serpent. From a seal-cylinder in the British Museum. (From *The Babylonian Legends of the Creation*, British Museum Monograph, 1931, by permission.)

Although the universe thus described had been set in order by a superhuman being, it had not been brought under the control of natural laws. The planets and constellations executed their orderly motions because they were personal gods obeying commands. Their motions could be described by suitable mathematical devices, but they were not the product of natural causation. For the Babylonians and Egyptians the causes of events were personal forces, unique, arbitrary and unpredictable, known only in so far as they revealed themselves through their actions. Of natural law, of the uniformity of nature—the supposition that given the same circumstances the same cause will produce the same effect, of a particular event as an example of a type, deducible from a general theory explaining the type—they formed no conception whatever.

Greek Science

The strategic step taken in the sixth century B.C. by the earliest Greek philosophers, Thales, Anaximander and Anaximenes, all citizens of Miletus in Ionia on the coast of Asia Minor, was to assert that a single order underlay all the changes observed in the universe, and that man could comprehend that order; that everything happening in the universe was reducible to discoverable natural laws. This was the first and essential contribution made by the Greeks to the Western scientific tradition.

Like the authors of ancient myths, the men of Miletus were interested in the problem of the origin of the universe. But their method of giving an answer was quite new. They were practical men—Thales was an engineer and statesman, Anaximander a map-maker, and both were apparently interested in astronomy; their city, an important commercial centre, was a channel through which Egyptian and Babylonian technical skills reached the Greek world. They tried to account for the origins of things not in terms of an arbitrary struggle between superhuman beings, but in terms of changes in an underlying substance regulated by discoverable laws. Thales called this substance 'water', Anaximander 'the indefinite', Anaximenes 'air'. They held that the primitive mass of uniform substance separated into parts, some hotter and some colder, some wetter and some dryer; this separation produced motion, and so, by a series of changes, the universe was brought to its present state. This has obvious analogies with the Babylonian myth, *Enuma Elish*, and also with the story of the generation of the gods described by the Greek poet Hesiod. The important difference is that in place of a *story* of individual gods, the Ionian philosophers put forward a *theory* accounting for things by impersonal processes obeying uniform laws. A good illustration of this is Anaximenes' reduction of the whole process of the production of things to one of rarefaction and condensation.

> When it [air] is dilated so as to be rarer, it becomes fire; winds, on the other hand, are condensed air. Cloud is formed from air by felting; and this. still further condensed, becomes water. Water, condensed still more, turns to earth; and when condensed as much as it can be, to stones.

About three-quarters of a century after Thales first conceived of explanation by means of uniform natural laws,

Fig. 2.—A water-colour painting of Bramble (*Rubus fructicosus*), from a copy of Dioscorides' Herbal made in A.D. 512, now in the possession of the National Library, Vienna. (From Wilfrid Blunt's *The Art of Botanical Illustration*, 1950.)

Pythagoras in South Italy, on the other side of the Greek world, took a step that was to lead to the second major Greek contribution to the Western scientific tradition. Pythagoras asserted that the physical world was reducible to, or explicable by, *mathematical* laws. One of the most important discoveries attributed to him is that the relation between the lengths on the string of a lyre between the places at which the four principal notes of the Greek scale were sounded, was 6:8:12. This gave the octave (12:6), the fifth (12:8), and the fourth (8:6). As a result of this discovery it was argued that, as sounds could be reduced to numbers, so could everything else; the essence of things could in some way be completely expressed in numerical terms: "Things are numbers". This marks the beginnings of the use of mathematics as a tool of *scientific* research, as distinct from purely practical research, as an instrument with which to investigate by abstract theory into the nature of the physical world.

The next important step towards the mature Greek conception of a scientific theory was taken by Parmenides of Elea, a member of the Pythagorean Brotherhood in the first half of the fifth century B.C. He pointed out that one homogeneous substance, as conceived by the Ionian philosophers, could in fact never change and give rise to the variety of things in the universe, but must remain permanently one and homogeneous. Parmenides himself was content to accept this conclusion and to deny that change was real: he said that the real was a permanent identity grasped

by the intellect, but out of the range of the senses. It may be difficult for us now to realise the full magnificence of that denial, yet it is one of the most splendid moments in the whole history of Western philosophy: it represents the first triumph of theoretical reasoning over the naïve evidence of the senses. Parmenides' arguments forced his successors, attempting to account for the changes actually observed all round them in the universe, to devise entirely new systems, involving theoretical entities far removed from direct observation, to avoid his dilemma. In the fifth century B.C. these all had a broadly common form. Instead of a single, homogeneous primitive substance they postulated a plurality of basic entities by whose rearrangements in space they explained change. The best-known example of this kind of system is the atomic theory of Leucippus and Democritus.

The final Greek conception of theoretical scientific explanation was formulated by a group of mathematicians who gathered round Plato at Athens in the first half of the fourth century B.C. Their contribution was to establish, as the programme for science, the reduction of the physical world not to the arithmetical laws of the Pythagoreans, but to *geometry*. The change seems to have been initiated by a crisis within the Pythagorean Brotherhood itself. Some Pythagoreans had supposed that the basic entities were points or units of substance, and that these could combine to form lines and geometrical figures. Thus a line consisted of a finite number of points, and the ratio of the lengths of lines was the ratio of the numbers of points they contained. This conclusion, and the whole Pythagorean programme for theoretical physics, was shattered for ever by a brilliant discovery: it was discovered that the ratio of the diagonal to the side of a square could not be expressed by an exact number, but was $\sqrt{2}$. Therefore geometrical bodies could not be built up out of discrete numbers of points. Tradition tells us that the Pythagorean who revealed the secret of the incommensurability of the diagonal and the side of a square was drowned at sea by the scandalised Brotherhood. Whatever credit we may give to this story, it is certainly true that it was the recognition of this incommensurability that led Greek mathematicians to re-examine their basic assumptions. They found a way out of the Pythagorean *impasse* by taking not numbers, but geometrical entities as the primary entities for physical theory.

Plato himself gave an example of the new method of explaining the physical world in his *Timaeus*, an imaginary dialogue between Socrates and Timaeus, a mathematician. Timaeus presents a geometrical story of the origin of the universe; it was, as Plato described all physical theories, a 'likely story'. His account resembled the ancient myths in that it explained the present state of the world by telling the story of how it came about. It did something entirely new, and was in complete contrast with the pre-scientific myths, in that the story was presented as a process of deduction from a geometrical theory. Very briefly, Plato assumed three basic entities: geometrical shapes, a disorderly chaos, and a principle of reason, a god which he called the Demiurge. The point of the myth was to show how the regularities of the actual, observed world could be explained by supposing that the Demiurge, not arbitrarily but because he embodied the principle of reason, imposed order upon chaos by reducing it to geometrical laws. He reduced the movements of the heavenly bodies to circles, built up chemical substances out of geometrical solids made by arrangements of triangular faces, constructed the human sense organs to that the quality of a sensation depended on the shapes of particles of air or fire entering them. This was the most ambitious attempt at a complete geometrisation of physics made in the Ancient World.

The myth of the *Timaeus* is primitive science, in that it was far-reaching speculation based on the sudden grasp of a wonderful new idea. It may be compared with Descartes' cosmological speculations, of which indeed it is a direct, if remote, ancestor. More modest in range and more precise was the use of the geometrical method by other Greek investigators, who controlled their theorising by strict canons of criticism. These men bore the great names we know in Greek mathematical physics: Eudoxus, Callippus, Euclid, Aristarchus, Archimedes, Apollonius, Hipparchus, Ptolemy, and many others who laid the foundations of geometrical astronomy, statics, optics and allied sciences, as we know them. Aristotle's logic also took as its model the method of thought used in geometry; so did even the Greek biological sciences.

The logical structure of the explanations offered in all the great classics of Greek science has a common form. The essential characteristic of the method is that it aimed at being strictly axiomatic. Whereas the Babylonian mathematicians had proceeded by tabulating the results of numerous trials, the Greeks showed that an indefinite number of particular conclusions could be deduced from a few axioms and other clearly defined first principles. To explain a particular conclusion or phenomenon, constituting the problem at issue, the investigator looked for premises from which to deduce it. A clear account of this method is given in the third book of the *Optics* attributed to the astronomer Ptolemy, who lived at Alexandria in the second century A.D., towards the end of the great period of Greek science:

> In seeking knowledge in any field we must start with certain general principles, and must make assumptions which are definite and self-evident either from the point of view of their practical effect or of their internal consistency. Only from such assumptions may the subsequent demonstrations be derived.

This describes perfectly the procedure followed, in his *Elements of Geometry*, by Euclid, who was a member of Plato's Academy about half a century after Plato's death. The whole series of theorems comprising this work is shown to follow by strict deduction from the definitions, postulates and axioms enunciated at the beginning. Accepting the premisses of a theorem, the conclusion is inescapable, though it may need considerable ingenuity to prove it. The proof is the explanation.

Some examples will illustrate the use of this method in particular sciences to which the Greeks made outstanding contributions. The purpose of each investigation was to solve a problem, for example to explain the action of a mirror, a refracting medium, or a lever, the behaviour of floating bodies, the regular motions of the stars and planets.

In his *Optics* Euclid began, exactly as in his *Elements*, with a set of postulates: "Let it be assumed: 1. That the

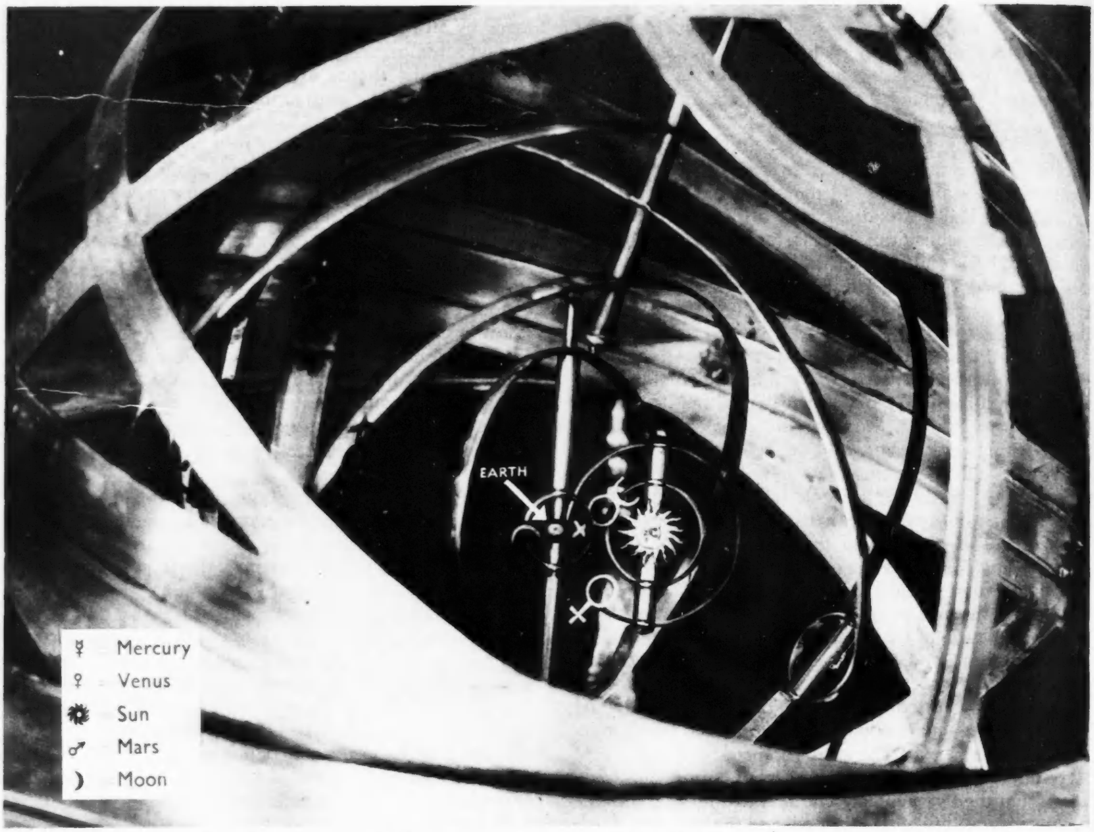

FIG. 3.—Central part of an armillary sphere made in Italy at the end of the seventeenth century to illustrate the astronomical system of Heracleides of Pontus. The earth is represented as the centre of the system; around it are arranged the orbits of the five other heavenly bodies. Each orbit is a metal ring bearing its appropriate planetary symbol; the key to these symbols is provided in the panel in the corner of the photograph. (Museum of the History of Science, Oxford, by courtesy of the Curator.)

rectilinear rays proceeding from the eyes diverge indefinitely; 2. That the figure contained by a set of visual rays is a cone of which the vertex is at the eye and the base at the surface of the objects seen; . . . 4. That things seen under a larger angle appear larger, those under a smaller angle appear smaller, and those under equal angles appear equal"; and so on. From these were deduced a series of geometrical theorems about the elementary phenomena of vision.

Archimedes, a younger contemporary of Euclid, began his famous treatise *On the Equilibrium of Planes* with a set of postulates based on experiment: "I postulate the following: 1. Equal weights at equal distances are in equilibrium, and equal weights at unequal distances are not in equilibrium but incline towards the weight which is at the greater distance; 2. If, when weights at certain distances are in equilibrium, something be added to one of the weights, they are not in equilibrium but incline towards the weight to which the addition was made. . . . " From the complete set of seven postulates were deduced the properties of the lever, laying the foundations of scientific statics.

The most impressive achievement of Greek science was in astronomy. Here a succession of theories was tried, one theory being replaced by another found to be more accurate, or geometrically more convenient. In the fourth century B.C. Plato's pupil Eudoxus founded the geometrical science of astronomy by showing that the most striking phenomena of a planet's motion, retrogradation, a return on its path through the fixed stars, could be described by a geometrical model assuming that each planet was borne on a sphere and by arranging a simple combination of spheres concentric with the earth. (The sun and moon were included in the planets.) Eudoxus' system was improved later in the fourth century B.C. by Callippus, but a weakness of the system was that it assumed that the distance of each heavenly body from the earth was constant. With this assumption it was impossible to account for such obvious phenomena as the variation in the apparent brightness of the planets and in the apparent diameter of the moon, which sometimes

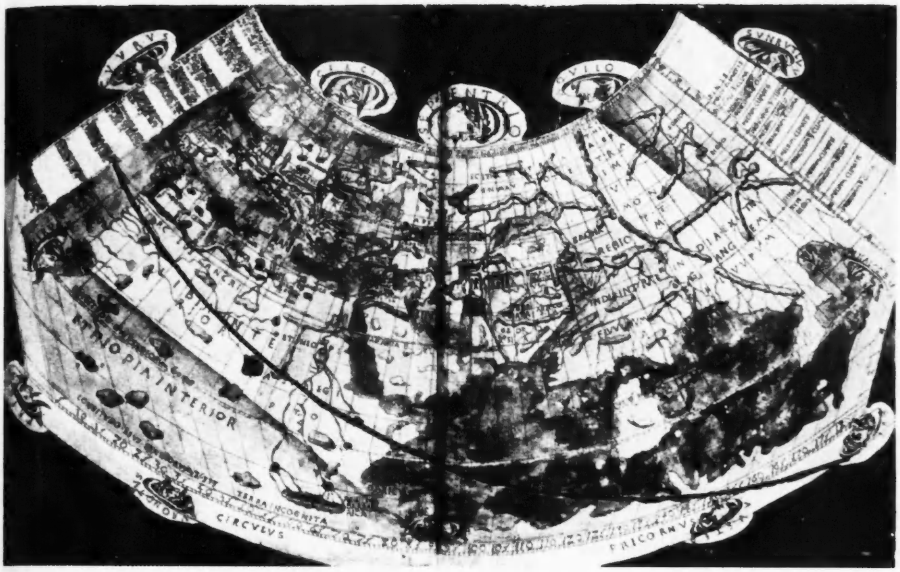

FIG. 4.—Ptolemy's map of the world, from the Cosmographia Bologna, 1477. (British Museum copyright.)

totally disappeared in an eclipse and sometimes was seen as a ring of light. Several different theories were put forward by later Greek astronomers to deal with this and other problems. One system was that put forward in the fourth century B.C. by Heracleides of Pontus (Fig. 3); in this, Mercury and Venus revolved round the sun, while the moon, the sun, Mars, Jupiter and Saturn revolved round the central earth. Another system was devised in the third century B.C. by Aristarchus of Samos, with the earth, moon and all the planets revolving round a central sun. The system that eventually supplanted all the others was that of Hipparchus, who based it on the geometrical devices of epicycles and eccentrics introduced by Aristarchus' younger contemporary, Apollonius. Ptolemy's account in his great work, the so-called *Almagest*, established this system until the time of Copernicus; its basic principles were enlarged only by Kepler and Newton.

Greek science as seen in these examples was a triumph of order brought by abstract thought into the chaos of immediate experience. In the search for what was permanent in the changing world of observation, the Greeks hit upon the brilliant notion of a generalised use of scientific theory, of assuming a permanent, uniform, abstract order from which the changing order of observations could be deduced. Greek science brought the entire realm of natural causation covered by ancient technology and mythology into a single, common circle of criticism. Its theories became a new set of *scientific* 'myths', whose power to explain was consciously understood and could be extended to wider and wider fields because it was under accurate control. If the Greeks lost anything as compared with their predecessors, it was in the actual technical application of their discoveries. That was partly because they were not very interested in technology, and partly because, then as now, theoretical work can rarely be immediately applied at the engineering level.

The Greek ideal of reducing the physical world to geometry has been the greatest force of inspiration in the whole history of Western science. It stimulated the best work of the Arabs, of the medieval West, of Galileo and Newton and their successors down to Bohr and Einstein in the present century. Our modern conception of scientific explanation is precisely that formulated by the Greek geometers. But there is one obvious difference between Greek methods and those used in modern science, as described at the beginning of this article. Though the Greeks made observations and experiments to investigate problems and confirm theories, they formulated no systematic methods of induction and controlled experiment, especially for analysing complicated problems involving several variables. In the next article we will see how these were developed in the West during the later Middle Ages.

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M.I.T. today occupies a fine site in Cambridge on the banks of the Charles River, to which it moved in 1916 from its original home in Boston. M.I.T.'s charter was granted in 1861, but it did not open its doors until after the American Civil War had ended. It was the first U.S. institution to provide technological training at university level. Today the research side of its activities is as important as the teaching side, and the two are looked upon as interdependent and mutually essential.

The Massachusetts Institute of Technology

P. V. DANCKWERTS, M.A., S.M.

There has lately been a great deal of discussion about the methods by which we can train more technologists and applied scientists than we do at the moment. All are agreed that the need is urgent if we are to increase or even maintain the efficiency of the industries on which we depend. Opinion is divided as to whether the best way to achieve the object is to strengthen our technical schools and the technological departments of our universities; or whether we should have one or more technological schools of university status, for which M.I.T., the great American engineering college, might be taken as a model. There has seemed at times to be some vagueness about the actual aims and functions of M.I.T. Some facts and figures and some personal impressions may help to form an idea of what M.I.T. has done, what it hopes to do, and how many of its features could profitably be copied in this country.

* * * * *

"The tomb of the dead languages." So was M.I.T. referred to in a Boston paper not long after its opening in 1865. The phrase aptly expresses the emancipation of the Institute's aims and methods from the classical tradition in education. It has always been free to pursue, by whatever means currently seemed best, the objectives of its founder, William Barton Rogers, who aimed at ". . . instituting and maintaining a school of industrial science, and aiding generally by suitable means the advancement, development and practical applications of science in connection with the arts, agriculture, manufacture and commerce". However, those responsible for the Institute's educational policy have tried fairly consistently, and with some success, to avoid the danger of it becoming a narrow and crabbed vocational school.

From the outset M.I.T. turned out men who understood and believed in the campaign of material development which has been the real history of America. The technologist has been, in a sense, the aristocrat of America. He has always been an important member of the community and has contributed to the national philosophy, "the American dream". He plays a greater part than the British technologist in the higher control and management of industry. If the technologist is to be one of the architects of society, he must be given an education of sufficient breadth to enable him to see beyond his specialised professional interests. The problem of providing a broad education in a technological institute is under intense scrutiny at M.I.T., as will be seen later.

The educational activities at M.I.T. are divided into five schools—Engineering; Science; Architecture and Planning; Humanities and Social Studies; and Industrial Management.

The first three are those on which the present reputation of M.I.T. rests. The School of Humanities and Social Studies has only recently been organised as such. It is responsible for planning and administering the programme of general education which is part of the common curriculum in science and engineering, and will also offer both undergraduate and graduate degrees in Economics and Social Science. The School of Industrial Management has recently been founded, and its purpose is to train potential managers who will be fully cognisant of the scientific and technical basis of industry.

An undergraduate entering M.I.T. normally takes a four-year course, each academic year consisting of two terms of sixteen weeks each. The subjects taken in the first year are common to all the courses, and comprise Chemistry, Physics, Mathematics, Engineering Drawing and English Composition. There are three hours a week of compulsory 'Military Science' (similar to the University Training Corps of our universities) and a two-hour athletic programme (instruction in swimming, games and sailing). A student need not finally choose his subject until the end of the first year. Basic, non-specialised courses in science, engineering or architecture appear in the second year. Courses in the specific professional subject of the student's choice (e.g. Chemical Engineering) do not appear until the third year. There are twenty such subjects to choose from; although some of them sound highly specialised (e.g. Food Technology), in fact only about a quarter of the student's time is occupied with 'professional' topics. It is proposed to institute a new course in Natural and Social Sciences, in which these specialised subjects would be replaced by courses in the humanities; it is felt that this curriculum will provide for those who do not intend to become professional engineers, but wish to study engineering as a variety of general education.

The Graduate School, which comprises about a third of the total number of students, and which draws about a third of its strength from outside M.I.T., offers more specialised professional training in the subjects for which the groundwork is laid in the Undergraduate School, together with degree courses in Economics and Social Science, and advanced Physics and Chemistry. An individual student has considerable freedom to compose his own programme from the large number of subjects offered by the department in which he is working, and by others, including pure science and the humanities. The degrees offered, in ascending order of status, are Master, Engineer and Doctor. The time required to complete the courses for these degrees will vary from case to case, but a doctorate will require at least two years. Research or other original work forms an important part of the course leading to each of the categories of degree. A candidate for a doctorate, in particular, is expected to make a substantial original contribution to his subject, as well as pursuing a course of advanced study on which he is given a formal examination. As in English universities, much of the research programme of the Institute is actually carried out by graduate students.

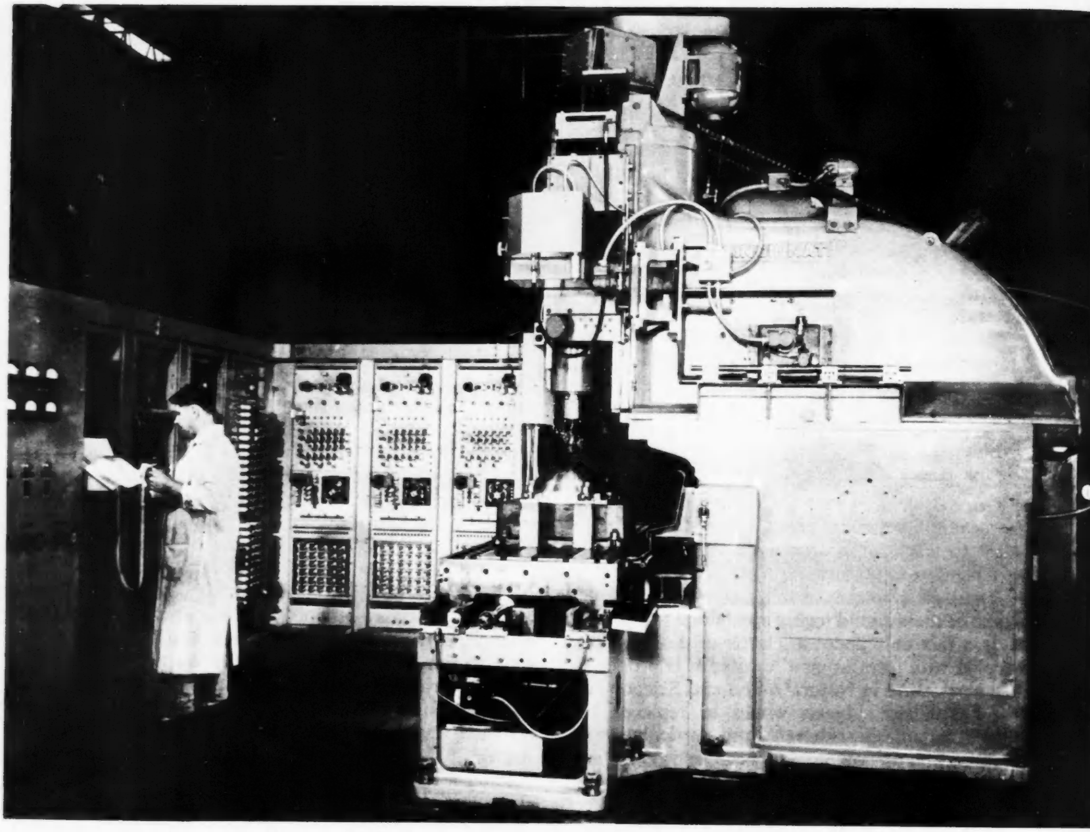
Personal Impressions

My own experience of M.I.T. was obtained as a graduate student in the Department of Chemical Engineering in 1946–7. After spending two terms in the Institute itself and six months in the Chemical Engineering Practice School, I obtained the degree of Master of Science in Chemical Engineering Practice.

Since I had not been called upon for serious mental exertion since taking a degree in Chemistry at Oxford in 1939, I expected to find the course a testing experience, but there was an element of severity in it which exceeded my expectations. I think anyone with a conventional scientific training in an English university might feel the same way, and would find the experience equally bracing.

My programme consisted of a number of undergraduate and graduate courses covering various aspects of chemical engineering, as well as some mathematics and electrical engineering and a small amount of research. Most courses were based on the 'problem' system, which means that each student works through a succession of numerical examples designed to bring out the principles of the subject while inculcating accuracy and diligence. The descriptive and literary approach, so familiar at Oxford, was almost completely absent. Many of the class periods were devoted to the discussion of these problems; the students—again how unlike Oxford!—being expected to recite and justify their own solutions on demand. Exchanges between instructors and staff were often lively. Some of the notable characters on the staff could, with nicely calculated insults, rouse the most torpid class to babbling indignation, or hold them attentive with anecdotes of factory and board-room. In each course there was a fortnightly 'quiz', consisting of a one-hour examination covering the past two weeks' work. In some courses there was a terminal examination as well, but there was no comprehensive examination for a Master's degree.

After a fumbling start, overwhelmed by homework and struggling to adjust my ideas, I found my feet and managed to keep up with the crowd. My chief practical weaknesses were in mathematics and in the art of arithmetic, which is so important for engineers. My formal deficiencies were in mechanical engineering subjects (which in fact play a minor part in Chemical Engineering as conceived at M.I.T.) and in humanities, since at Oxford one had been supposed to acquire culture by osmosis rather than formal instruction. The course did not provide insuperable intellectual difficulties for anyone with a good grounding in the basic sciences. For my part its value lay chiefly in supplementing and modifying the severely academic outlook acquired at Oxford. The difference in attitude can be summed up in the statement: "Scientists solve the problems they can, engineers solve the problems they have to." An engineer uses scientific methods as a valuable tool, but knows that few engineering problems are capable of a rigorous formal solution. He also knows that it is often better to have the answer within a factor of two tomorrow than to have it within ten per cent in a year's time. I should have been forced to recognise the same things in any engineering school, of course; the special virtues of M.I.T. lay, I believe, in the enthusiasm and intellectual liveliness of the staff, their ability to correlate the scientific and technical aspects of the subject and their personal experience with industrial developments. In addition, they spared neither themselves nor their students when it came to sheer hard work. M.I.T.'s unofficial slogan is "Tech. is Hell".



Research at M.I.T. has provided the basis of many new inventions and developments. One of the latest machines with which M.I.T. has been concerned is this numerically controlled milling machine. The machine operates by instructions transmitted to it as numbers. This information is fed to the machine on a punched paper tape; this is decoded electronically and translated into a sequence of milling operations which results in the production of metal components each drilled with holes of the desired dimensions and in the correct places.

My criticisms would be that the students had too little time or encouragement for speculation and criticism; that there was no system for individual tuition (seminars might have been a practicable alternative); and that too much time was devoted to worked examples, too little to considering the physical basis of the problems. However, much has probably changed since 1947.

The Chemical Engineering Practice School is a justly celebrated institution. The student spends two months in each of three different factories: a pulp and paper mill in Maine, an iron and steel works in Buffalo, and a nitro-cellulose plant in New Jersey. In each of these factories the Institute maintains an assistant professor as Director of Studies, and his assistant. The firm provides office and laboratory accommodation. The Director selects a series of problems which have arisen in the factory and presents them in suitable form to a team of students, who must carry out the necessary investigation and recommend appropriate action. Not more than twelve students are working at one time at any station, and they may be divided into smaller groups for specific problems.

The Practice School course has a number of objects. Students get technical acquaintance with the various manufacturing processes, experience with standard equipment such as condensers, pumps, valves and so on, and some appreciation of the difficulties of actual plant operations and investigations. Well-chosen problems can give valuable education in fundamentals; the laws of radiation, for instance, will be granted something more than intellectual assent in a steel plant. There is also a deliberate and incidental cultivation of what might be called the 'public school' virtues—leadership, team-spirit, tact, initiative and so on. This is achieved by living and messing together, working as leader or member of a small team, and having to placate workmen, foremen and management. Great stress is laid on the communication of ideas and information, by means either of meticulously presented and ruthlessly criticised reports or of short informal talks. Finally, there is the grim discipline of the 'Deadline'; reports must be in at the stated time, and there is no appeal.

An Engineering Practice School, open to graduate students from any department of M.I.T., has been instituted

since the war at the Atomic Energy Commission's plant at Oak Ridge.

M.I.T. as a Model

There are a number of reasons why we should be cautious in trying to use M.I.T. as a copy-book model for a technological school in Britain. Many of the admirable features of M.I.T. are products of a long period of growth and development; they therefore cannot be bought and incorporated into a brand-new institution.

Starting in 1865 with modest resources, a staff of six and a student body of fifteen, M.I.T. now has an annual income of $23,000,000, 5000 students, over 1000 other research workers, a faculty of 436, and a large investment in buildings and equipment. This is the scale of operations of a fair-sized university—for instance, Cambridge has 8000 students and a faculty of 670—and has only been reached as the result of developments spread over eighty-seven years.

Size is not unrelated to the quality of a teaching institution. In this country there is a tendency for individual universities to specialise in different branches of technology. The department concerned will be ably staffed, and will grow to a considerable size because the reputation of the staff attracts students and support. At M.I.T. each department is outstanding in its own line, and is able to attract students not only from every state in the U.S.A. but also from other countries. Leading men in a number of different branches of science and technology are brought under one roof; this leads to a profitable exchange of ideas and enables their personal influence to reach a larger number of students. A large institution can also make economical use of the expensive equipment required in teaching some branches of engineering. Nevertheless, it is realised at M.I.T. that there is an optimum size for the Institute, and that its field of activities should not be indiscriminately widened.

Reputation is an asset which increases snowball fashion; once a teaching institution has achieved a brilliant reputation it will attract brilliant men, but the process is hard to start. A special difficulty faces a technological school—competition with industry for the best men. M.I.T. offers its staff prestige, and although its salary scales do not compete with those in industry there is opportunity and encouragement to act as consultant to commercial organisations. This provides not only a supplementary source of income for individuals, but also a liaison with industry which is of enormous benefit in keeping teaching and research work topical and relevant. The reputation of M.I.T. rests, of course, on the quality of its graduates as well as of the staff. Here again, once an institution has established a reputation it can be highly selective in admitting students and rigorous in weeding out those who do not keep up to the standard. M.I.T. is in this position; thus we find that the total number of applications for admission in September 1951, for example, was over 3000, leading to the registration of only 900 students; moreover, the average ability of the *applicants* was probably already well above that for the remaining colleges and universities in the country.

Over half M.I.T.'s income is at present derived from Government research contracts, which are non-profit making. (The payment on such contracts is sufficient to cover the actual costs of the work, including overheads, salaries of full-time workers and a share of the salaries of staff members taking part in the work.) This service to the Government is largely a product of the war years; it includes a great deal of work which in this country would be done by the D.S.I.R. or by other Government agencies. (Some research work is done at M.I.T. for industrial firms though this represents a relatively small item compared with the Government-sponsored research effort; a small profit is made on this kind of research contract.)

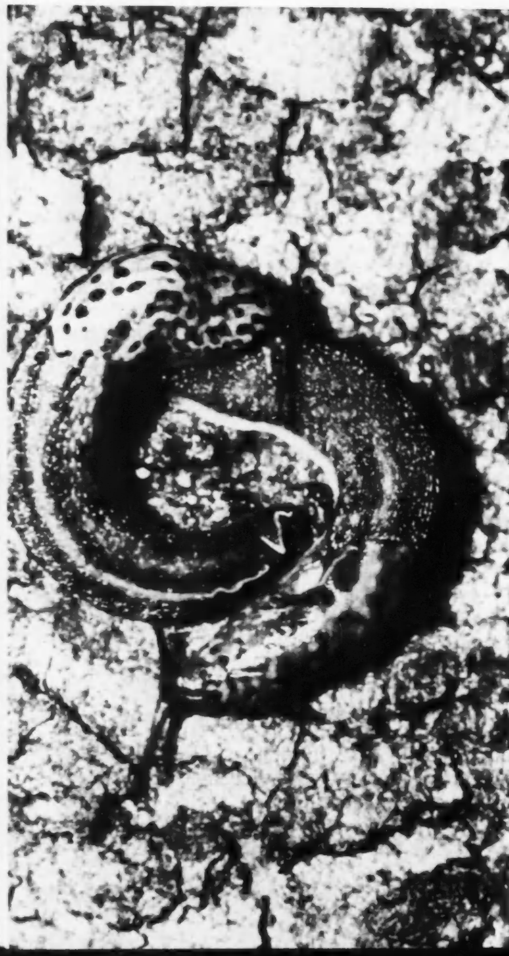
Some misgivings are felt about the magnitude of the Government-sponsored research programme undertaken by M.I.T. This programme has meant that M.I.T. has become involved with security requirements, *ad hoc* development work, multiplication of administrative duties and similar matters presenting dangers which must be guarded against. On the other hand, the research work of many graduate students is financed by these contracts; this system of Government sponsorship also brings the advantage that expensive facilities (such as wind-tunnels) are added to the range of M.I.T.'s equipment, and are available to all M.I.T. workers, thus making it possible to do certain work of a fundamental nature which would otherwise be too costly. It is also regarded as one of the functions and duties of the Institute to provide these services to the Government and to industry.

It is in keeping with American distrust of Government influence and passionate belief in private enterprise that M.I.T. should take a pride in receiving no *direct* Government subsidies. (The research contracts, as already mentioned, yield no profit.) The income available to the Institution for educational purposes is derived from endowments, students' fees and voluntary contributions from firms and individuals.

Finally, it would be unimaginative for us to model a technological institute on M.I.T. in its present form. M.I.T. must be viewed as a moving target, and we should aim ahead of it. In 1947 the faculty appointed a Committee on Educational Survey, which reported in 1949. This remarkable report is far from complacent in tone. Many topics are critically dealt with—for instance, the optimum size of the Institute, the scale of Government-sponsored research, undergraduate education, the programme of humanities and improvements in staff environment. A large number of recommendations were made, ranging in scope from general statements of principle to concrete proposals for action. The general theme of the recommendations is that M.I.T. should take on the character of a university offering an education based on science and technology, and that the quality of undergraduate education should be greatly strengthened. Even more remarkable than the self-critical and radical nature of the proposals is the fact that they are already being whole-heartedly acted on.

I do not suggest that our needs and objectives in technological education are exactly the same as those of America, but I feel that if we are to establish a technological institute in this country, among the features we should try to copy from M.I.T. are the independence and enterprise which have made possible this reform from within.

THE AERIAL MATING OF THE GREAT SLUG



THE Great Slug, *Limax maximus*, is a native British species to be found in our woods, hedges and gardens; it has been introduced to many other countries. The accompanying photographs of its remarkable mating process (which it shares with varying details with other allied slugs) were taken in North America, where this mollusc goes by the name of the Black Slug. These pictures, by Lynwood M. Chace, show the slugs in their natural environment.

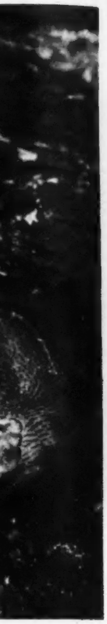
Slugs are hermaphrodite, that is, they have both a male and a female set of reproductive organs in the same animal. There is a common genital pore (situated close to the head of its right-hand side) so that self-fertilisation is possible, but cross-fertilisation is the rule.

At mating time in the late summer or autumn the slugs pair on the undersides of tree branches. After some preliminary caressing with their tentacles, they begin to circle each other at the same time secreting a copious amount of mucus. This may go on for 30 to 90 minutes and all the time the mucus string from one becomes entwined round that of the other. Then the circling narrows and the slugs launch themselves head-first into the air and at the same time twisting their bodies around each other. They are prevented from falling to the ground by a thick mucus cable attached on the tail-end of each. The object of the circling is now seen to be not only the preparation of a firm attachment to the tree branch but also the production of a mucus cable from which to hang; the latter may be up to eighteen inches long.

Once the slugs are suspended the white male copulatory organs are protruded (as is shown in the diagrammatic sequence on the right); these are cylindrical at first, the tips become club-shaped and then much frilled before twisting together in a tight spiral. Next an umbrella shape is assumed and the free edges, which are very mobile, effect a mutual transfer of sperm masses (which in the meantime have travelled along the sperm duct inside each copulatory organ) from one animal to the other. During mating the bodies of the slugs are flaccid and the tentacles are collapsed and partially retracted because much of the blood in the haemocoele has been employed to extend the copulatory organs which reach to about 4 inches beyond the heads of the animals.

When mating is complete, the copulatory organs are unwound and are drawn up into the bodies of the slugs. First one slug turns round and climbs up the mucus cable to safety and the other follows suit. Then they part, each to seek a damp, moist cranny—at the roots of trees, under logs or such suitable spot—in which to lay a batch of eggs.

The oval eggs, of about 5 mm. in length, are of a translucent amber colour, and soft and gelatinous to the touch. As the embryos develop the eggs gradually become opaque, and after about a month the young slugs are born.



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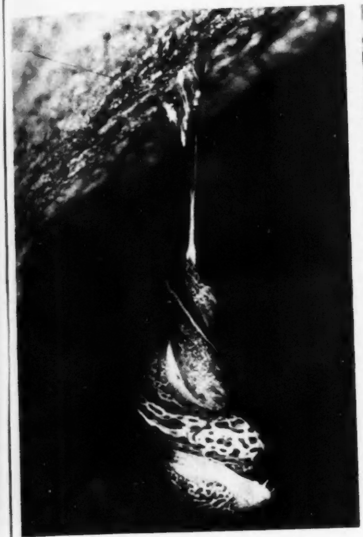
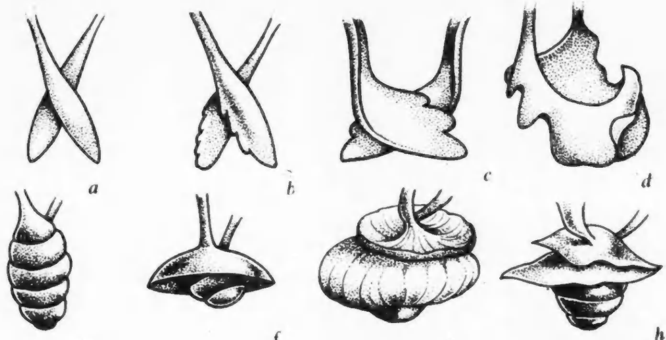
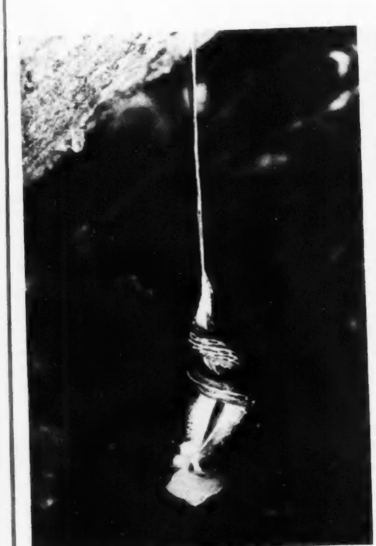


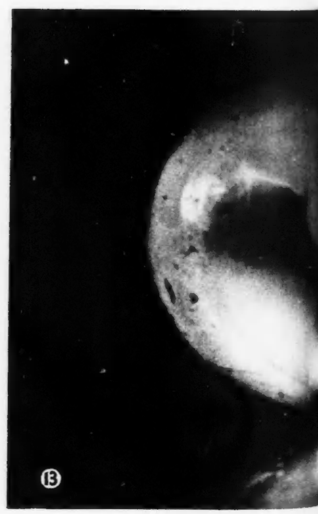




9. After mating the animals separate and crawl back along the mucus string until they reach the tree.

10. In due course each of the pair of slugs deposits a clutch of eggs.

11. The mass of eggs is laid about an inch deep in damp earth in shaded places.



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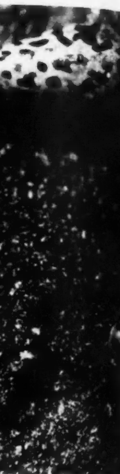

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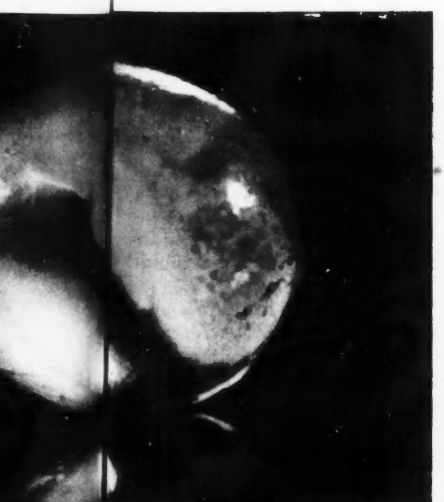
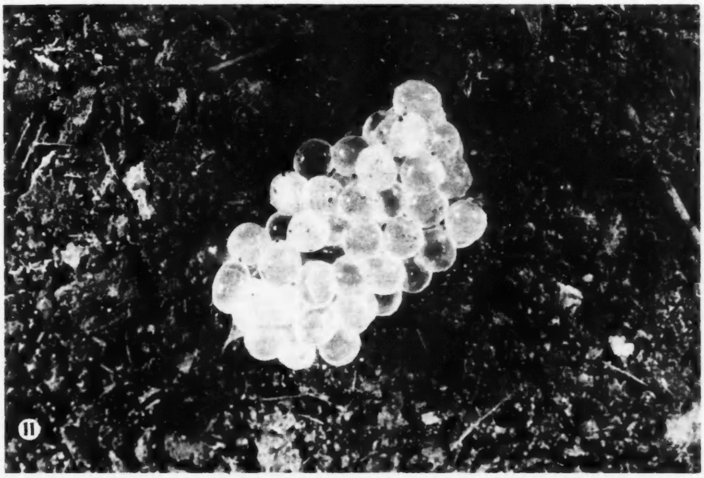
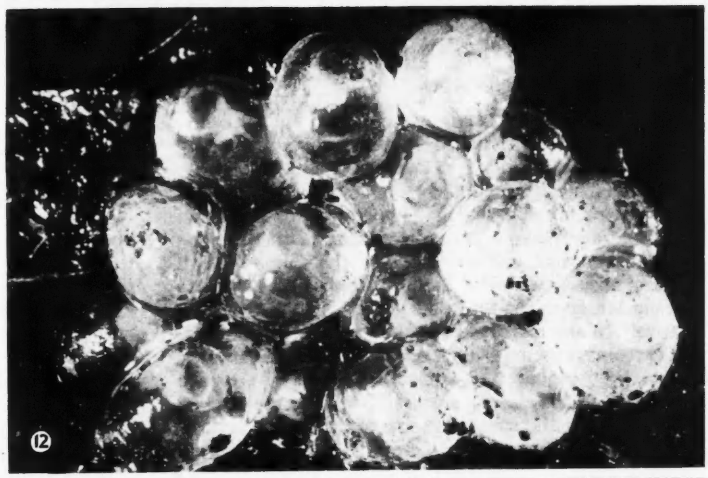
12. Close-up of egg cluster. The developing embryos can be seen inside the transparent eggs.

13. A single egg magnified; the embryo almost fills it.

14. The baby slugs which emerge from the eggs are only an eighth of an inch long; the full-grown adult is six inches in length.







The Geology behind Bricks and Cement

FREDERICK A. HENSON, B.Sc., Ph.D., F.G.S.

In my earlier article, which appeared in the September issue, we considered the origin, composition and physical properties of many rocks used in building, both in the past as well as the present. Nearly all the rocks described in that article can be classed as true building stones; for, apart from trimming and dressing by the quarryman and mason, they are used in their natural state. Now we come to materials which undergo physical and/or chemical changes before they reach the builder. These include clays, limestones and minerals such as gypsum and bauxite, which are the raw materials from which bricks, cements and plasters are made. These materials have come to be used in ever-increasing quantities to the extent that, in many modern buildings, they have completely replaced natural building stones altogether. It is the raw materials for these building materials which are discussed from the geological viewpoint in this article.

Bricks and Brick Clays

The traditional brick consists of a clay-sand mixture which has been either baked or burnt. The quality and properties of a clay brick are dependent upon the composition of the materials used, the processes it undergoes prior to baking or burning and the temperature at which that final stage is carried out. The use of fire to harden clay was one of the early milestones along civilisation's road; archaeologists have found fired clay bricks of very early times in Mesopotamia (*c.* 3400 B.C.) and Roman bricks are relatively common archaeological objects in this country.

The Romans used a thinner brick than the ordinary type in common use today; their bricks, tiles and pipes were made by firing prepared clays in small kilns which were fired by wood, charcoal and coal. On some of their bricks scraper marks and thumb marks of these early brick-makers are still to be seen. (The scraper is a wooden tool used to pare off the surplus clay from the rough brick as it is being shaped in the mould.)

Since Roman times a great variety of bricks have been produced, and put to many different uses. Within the last two centuries bricks have become the builders' commonest material, a fact which is frequently deplored by many critics who regret the monotony of the interminable rows of brick-built houses which line the streets of so many cities, towns and suburban areas. With the common use of bricks there had developed a series of standards, not only for bricks and brickwork, but the uses to which they can be put. During this time the old-fashioned and small hand-made bricks have been replaced by the machine-made product which are produced in thousands of millions annually.

The materials suitable for brick manufacture consist mainly of clays, shales and fireclays. Clays are the result of the decomposition of rocks containing a high proportion of felspar, and have either accumulated near to their parent rock or, as described in the first article, they have been redistributed as sediments. Clays vary enormously in their colour and composition; they also differ in respect of the amount of sand grains, calcareous matter and minerals containing manganese, sodium and potash which they contain in addition to the clay minerals. The latter are hydrated aluminous silicates and are colloidal in nature; some clays also contain a proportion of aluminium oxides. Some clays contain combustible organic matter as well; and, under ideal conditions, this organic matter assists in the firing of the brick, making that more complete and reducing slightly the amount of coal required in the process. The presence of various metals in the clay may impart a particular colour to the finished brick, and this can give a special popularity to the product of an individual brickfield. The ideal brick clay contains approximately 60% silica (SiO_2), nearly all of which is in the form of silicate; too high a proportion of combined silica in the composition of the clay results in bricks which lack strength and cohesion, whilst too small a proportion results in excessive shrinkage. The last-mentioned phenomenon is due to the fact that the larger the proportion of clay there is in the brick the larger the amount of water the undried brick contains and loses on firing. Too much lime in a brick clay causes the bricks to melt and slump in the kiln; this is wasteful because of the high proportion of deformed bricks which result.

The most important sources of brick clays in this country are from rocks of the Carboniferous and later periods. Rocks older than the Carboniferous period are rarely used, since in their long history the original clays and shales have been so altered by earth movements and pressures that they have lost the physical properties indispensable for brick-making material. (The principal changes are the loss of the original high water content of the clays and the growth of new mica-like minerals; the resulting materials lack both the colloidal character and essential plasticity which one associates with clays.)

In some parts of Wales clays older than the Carboniferous which have escaped any considerable metamorphosis are used; the most important sources in this category lie in Caernarvonshire, the Fishguard area and in Central Wales.

Of the Carboniferous rocks the Coal Measures provide clays suitable for brick-making in nearly all the coalfields. The Northumberland, Lancashire, Yorkshire and South Staffordshire coalfields produce hundreds of millions of bricks each year using local clays and coals. In the Black Country the Upper Coal Measures, including the well-known horizons of the Ruabon and Etruria Marls, are used for making all kinds of bricks, including the Staffordshire 'blues'.

The upper part of the Triassic rocks, which form a great part of the surface rocks of the Midlands, are used for brick manufacture in Nottinghamshire, Derbyshire, Warwickshire and Worcestershire. The Keuper Marl is also used by a small number of brickworks in the West of England and South Wales; due to the large amount of iron in the marls of this stratum the burnt bricks have a pleasing red colour.

The most important brick clays in this country are of Jurassic age; they form a broad belt of comparatively flat

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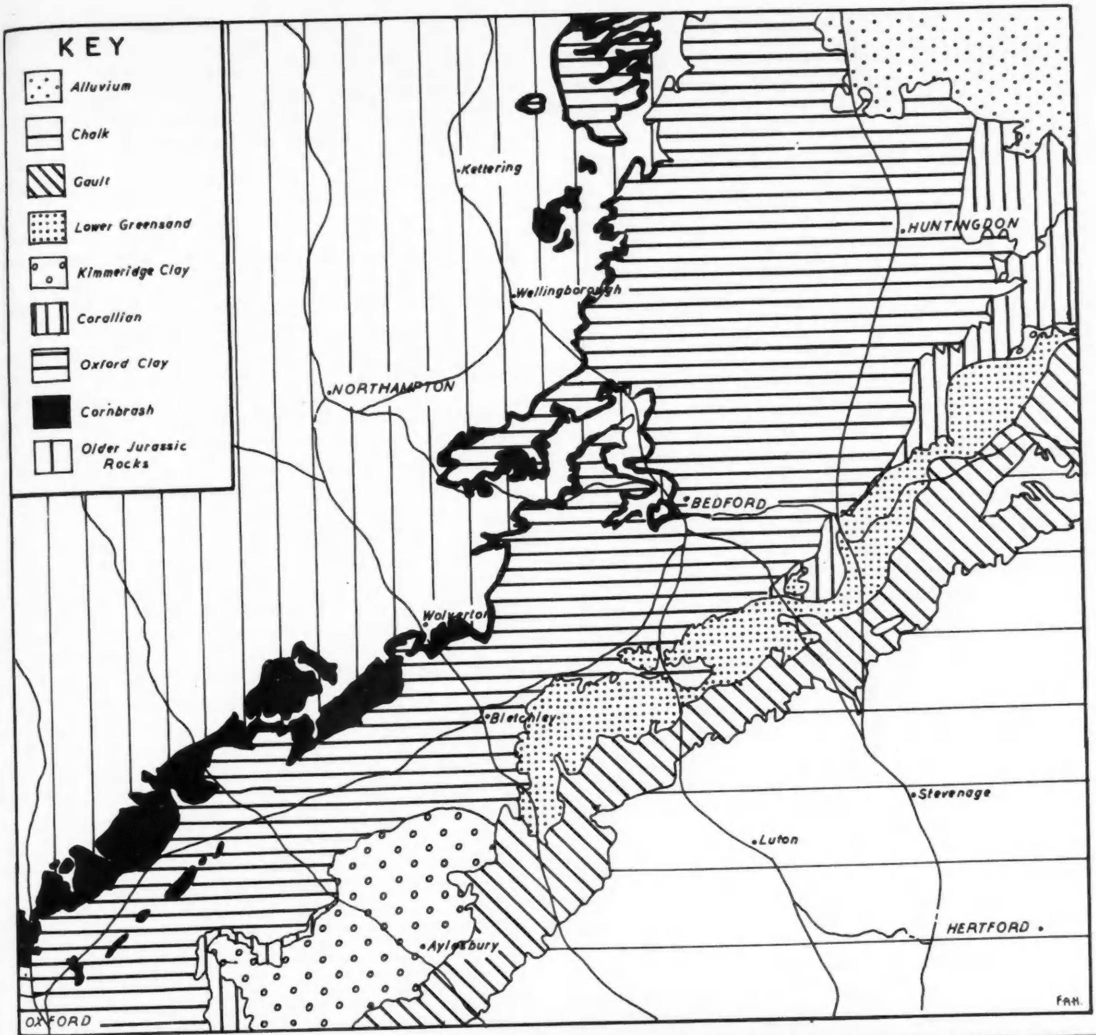


FIG. 1 (*above*).—Geological Map of parts of Bedfordshire, Buckinghamshire, Hertfordshire, Huntingdonshire, Northamptonshire and Oxfordshire, showing the main clay belt (the Oxford Clay and Kimmeridge Clay), which provides the raw materials for this important brick-making region. The older Jurassic rocks provide good oolitic limestones while the Greensands and Chalk are respectively used for building sands and for cement manufacture.

FIG. 2 (*right*).—An aerial view of the brickworks at Stewartby. The main L.M.R. railway line south of Bedford passes through the area. The Oxford Clay provides the raw material for three large brickworks shown in the photograph. Some idea of the depth of the excavations is shown in the newer clay pit in the left foreground, where the clay is seen leaving it in tubs.

(*Courtesy of London Brick Co. and Aerofilms Ltd.*)

country and are the younger members of the Jurassic series of strata. The two main clay horizons are the Oxford and the Kimmeridge Clays; these formations vary considerably in their thickness. Their outcrop is marked by a wide belt of brickworks extending from Peterborough through Huntingdonshire, Bedfordshire, Buckinghamshire and Oxfordshire and then onwards to the Dorset coast. The main centres of the industry are in the neighbourhood of Peterborough, Bedford, Bletchley and Calvert. Here the kilns are predominantly of the Hoffman type; their tall slender chimneys, often ten or more in a cluster, are conspicuous features on the relatively flat landscape.

Brick-making

After the overburden of soil and vegetable matter has been stripped off, the clay is usually worked in large pits, using long steps or benches. In this way clay from particular levels or geological horizons can be obtained and the layout of conveyor rails and exploitation of the clays planned to best advantage. The clays and shales are generally dug out by mechanical digger, loaded into skips at the face of the pit and transported to the works. Weathering may be the first of the processes which the raw materials undergo, although it is not always necessary. In some clays, especially stiff clays, exposure to the air, sun and frost, assists the subsequent processes by breaking down the material. This practice of weathering the clay entails double loading of the material, and is dispensed with except where it is essential; the usual practice is to transport the clays direct from the pit to the crushing plant.

The type of crusher employed depends upon the physical properties of the clay; for soft clays crushing rolls are used, whilst for the harder clays and shales jawcrushes (which masticate their charge) and pulverising machines known as cone granulators are used. When it is necessary to grind the material very fine, ball mills are employed. If a particular clay as quarried is unsuitable for immediate use in brick-making, then it may be blended to the requisite composition and consistency by mixture with either sand or chalk.

There are several different processes for making bricks; which particular process is used in a particular region depends largely on the physical character of the local clay. For both hand-moulded and wire-cut bricks the clay has to be first converted into a uniform thick paste. To achieve this condition the clay is first crushed and ground; it is then passed through a mixing trough and finally through a *pug-mill*, which works on the same principle as a sausage machine and mechanically cuts and kneads the clays which are then ready for conversion into either hand-moulded or wire-cut bricks. (In the latter case the plastic clays are stiffer than for hand- or machine-moulding.)

Moulded Bricks

To achieve uniformity in shape and size, the clay is either forced by machine into rotating steel moulds which automatically release the newly formed bricks; or it is pressed by hand into similar moulds, the bricks being then turned out like a cake from a tin.

To facilitate the removal of the pressed brick the brick-moulds need to be either lightly splashed with water, or sprinkled with sand. Sand sprinkling has the advantage of making possible special textures or colour finishes. The water-moulded bricks are wetter than the sand-moulded variety, and consequently take longer to dry.

Wire-cut Bricks

In the manufacture of this type of brick a column of plastic clay paste, about nine and a half inches in width and five inches in thickness, is extruded from a die attached to the pugmill. This column is then cut traversely by wires into bricks. The principle is similar to the extrusion of tooth paste from its tube, followed by transverse cutting into individual bricks.

Both hand- and machine-moulded bricks, as well as the wire-cut bricks, have to be dried after moulding. In the past natural drying by the wind, where the process took up to six weeks, was used. Today artificial drying, using waste heat from the kilns, is used and the drying period is thereby reduced to a few days.

In the third process, called the stiff-plastic process, the clay is first ground to a powder, then mixed with a small amount of water in a mixer to yield a stiff paste of a consistency similar to that of Plasticine. This paste is then fed into machines which press the bricks into shapes. To achieve a compact brick of uniform texture throughout, the pressing process may be repeated three or four times. These bricks are hard enough to be stacked as they come from the press, and they require no preliminary drying before firing.

The last method used is known as the semi-dry process, and is applicable to the harder clays and shales. The raw materials are first ground to a powder and mixed with a very small amount of water. The mixture is then moulded under great pressures using power-driven presses. This method, although comparatively simple, requires considerable skill in controlling and adjusting the machines.

After drying, the next stage is the firing process. At one time clamp burning, where the dried bricks were stacked with small coal in the open and fired, was very popular. This method has since been replaced by kiln burning. In small brickyards the intermittent kiln is favoured; this consists of a circular brick building which is open at the top and has holes at regular intervals around the sides; the walls are often strengthened with iron bands. The unburnt bricks are stacked inside, and the kiln is charged with small coal through the holes and main entrance until all the spaces between the raw bricks are filled. The top hole and the main entrance to the kiln are then bricked up with old bricks and the kiln is fired. The kiln usually burns for three or four days; and after leaving it for a period to cool down, the bricks are removed.

The larger kilns, particularly those found in the main brick-making areas, are the continuous kilns, known as Hoffman kilns after their inventor. These kilns, which first came into use in the 1860s, are rectangular in plan, and consist of a number of separate chambers each of which can accommodate up to forty thousand raw bricks. The chambers are fired in succession; so that at any time one-third of the kiln contains fired bricks which are cooling, one-third contains bricks drying prior to burning, and the remainder of the kiln is being fired. The fire travels round

the kiln and the hot gases are used for drying the unburnt bricks. An interesting fuel-saving point is that the air supply to the firing chamber is pre-heated by drawing it over the cooling bricks. The temperatures at which the bricks are burnt varies with the type of brick and the clays used; temperatures up to 1500° C. may be reached in the kiln.

Varieties of Bricks

Since there are a great number of brickyards in this country, many of which use clays from many different geological horizons and different methods of manufacture, it is not surprising that there is a great variety of bricks available for use by the builder. The bricks produced fall into three main groups: the common bricks for internal and outside walls where appearance is relatively unimportant; facing bricks where appearance is very important; and engineering bricks where strength and low porosity are essential. In the second group the finish and colour are determined by the manufacturer to suit the market. The third group, known as engineering or blue bricks, are burnt at very high temperatures which results in a hard, glassy surface. The clays used in the manufacture of these bricks contains 8–10% iron oxide, and their high density and hardness makes them suitable for damp-courses and structures where they can withstand exposure to a heavily polluted atmosphere. Most railway travellers will be familiar with these bricks which have been extensively used in bridges, cuttings and stations where they can withstand conditions under which ordinary bricks would disintegrate.

Fire bricks, used in domestic fireplaces, slow-combustion appliances, furnaces, etc., are made from highly refractory clays known as fireclays. These clays are rich in uncombined silica; they may contain as much as 90% of quartz. Bricks made from these clays can be recognised by their pale colour, even texture and smooth surfaces. Such bricks are often hand-moulded or pressed into many different shapes and sizes, and are fired at high temperatures.

Nowadays clay is not the only material used for brick-making, for in recent years sand-lime, concrete and coke-breeze bricks have come into widespread use in the construction of light internal walls where strength is not needed.

Cements

In its widest sense the term 'cement' describes a mixture which will bind together incoherent particles, such as sands or rock fragments, to form a solid coherent mass. In the building trade, however, cement means the 'Portland' cement of universal use. From earliest time builders have been aware that lime, obtained by burning limestone or chalk, is capable of hardening in contact with air—or in contact with sand and moisture, and once it has hardened it is practically impermeable to water.

Hydraulic cements made of burnt lime and sand were known and used by the Romans. Since then considerable advances have been made and today not only limestones and clays, but bauxite, gypsum and blast-furnace slag are used to produce a wide range of cements for every conceivable purpose. Special cements are also made for rapid-hardening, quick-setting and waterproof work.

When pure limestone, which may contain nearly 98% calcium carbonate, is burnt in the old-fashioned shaft kiln or modern rotary kiln it decomposes with the liberation of carbon dioxide and the formation of calcium oxide (quick-lime):

$$CaCO_3 = CaO + CO_2$$
$$\text{limestone} = \text{quicklime} + \text{carbon dioxide.}$$

When the quicklime has water added to it, considerable heating occurs and the lime swells at the same time. This addition of water is known as slaking, and this causes a chemical change which results in the formation of calcium hydroxide:

$$CaO + H_2O = Ca(OH)_2$$
$$\text{quicklime} + \text{water} = \text{calcium hydroxide.}$$

If the original limestone were impure and contained small amounts of clay, the slaking process would be less violent and the expansion which is produced would be less than in the case of pure limestone. Some clayey limestones are known as hydraulic limestones; on burning, these yield a mixture of lime and calcium silicates and aluminates. The more clay they contain, the lower the proportion of lime in the final product and the smaller the amount of expansion which occurs on adding water to the lime. With the finest hydraulic limestones, which contain up to 35% of clay minerals, there is little or no expansion. These limes are of economic importance because in two to four days they set to form a hard and insoluble cement. (In the trade, limes which are made from pure limestones are known as *fat limes*; those containing small amounts of clay are called *lean limes*, because of the fact that their bulk does not increase much when they are slaked.)

The setting process in a lime is the way in which it achieves its mechanical strength. In the fat limes it is simply a drying-out process, the material loses its plasticity as it dries and 'sets'. The mechanical strength of such limes is low; they are used mainly for internal plaster work. But with other types of lime, 'setting' is accompanied by chemical changes with consequent gain of rigidity and mechanical strength; one of the main reactions occurring is the combination of calcium hydroxide with the carbon dioxide of the air:

$$Ca(OH)_2 + CO_2 = CaCO_3 + H_2O$$
$$\text{calcium hydroxide} + \text{carbon dioxide} = \text{calcium carbonate} + \text{water.}$$

In the hydraulic limes the setting process does not involve combination with carbon dioxide, and these limes will set under water.

In some parts of Britain (notably in the lower Medway, Thames and Humber estuaries) alluvial muds and chalk provide the raw materials for the manufacture of 'Portland' cement.* The manufacturing process begins with the quarrying of chalk, limestone and clays. Where hard limestones and shales are used these materials are first passed through ball mills, and ground down. Then they are

* In 1756 Smeaton, whilst building the Eddystone Light, experimented with various cements to find the most suitable cement capable of hardening under water. He found that the best hydraulic limes were argillaceous. Much later (1824) Aspdin first used the word *Portland* to define a particular cement produced by the calcination of hydraulic limestone. It is interesting to note that Smeaton had said that cement made from such materials would "equal the best merchantable Portland stone in solidity and durability". Today the word 'Portland' describes the cement produced in the process described above; it has no real connexion with Portland but owes its popularity to Aspdin and Smeaton.

mixed in the rough proportion of three parts of chalk or limestone to one of clay by weight, sufficient water being added to make a slurry. Screening is essential at this stage to remove stones and flints. The slurry passes into tube mills where it is reduced to extremely fine particles capable of passing through meshes of 170 lines to the inch.

In the next stage the slurry goes into a long rotary kiln; the charge fed into the kiln is controlled by an analyst's reports. To achieve the correct charge the slurry is stored in two separate tanks; these are constantly agitated to prevent settlement. In one tank the slurry is kept with its lime content slightly above that required for the kiln charge; in the other tank the lime content is kept just below the final lime content required. By judicious blending of slurry from these two tanks uniformity of the charge fed into the kiln is maintained.

The kiln consists of a long cylinder (sometimes with an enlarged firing zone), which rotates slowly about its long axis as slurry is fed into the upper end and fuel enters at the other end. The fuel usually takes the form of very finely pulverised coal, although coal gas and fuel oil are used in some cement factories. The fuel is forced through the lower end and ignited. The hot air moving up the kiln dries the slurry, which passes slowly down to the firing zone, where it undergoes chemical changes at temperatures of 1200°–1450° C. The product that leaves the kiln is known as *cement clinker*. After cooling, the clinker is reduced to a fine powder by grinding or ball mills, small percentages

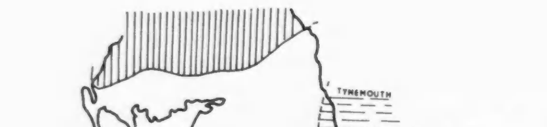


FIG. 3.—Map showing the extent of the inland sea known as the Newark Gypsum Lake which extended from Tynemouth through Newark and Gloucester to Watchet.

(1–4%) of powdered gypsum are added, which will control the setting process, and the final mixture is weighed, bagged and dispatched. In the tropics cement clinker is sometimes delivered to the building site where it is ground down to cement as required; this eliminates the risk of deterioration and wastage which is hard to avoid when cement in powder form is stored under tropical conditions.

Another category of cement is the aluminous cements which were first investigated in France with the purpose of producing a cement immune to the action of water with a high sulphate content. The raw materials in their manufacture are chalk and bauxite. The latter is an aluminous clay, which is the chief ore of aluminium; bauxite deposits, which are the result of decomposition of rocks rich in the felspars, are found in sub-tropical and tropical countries. The manufacture of this type of cement starts with the grinding and mixing of the chalk and bauxite. The mixture is then fed into an electric furnace and melted at 1500°–1600° C. The molten material is poured off into moulds; after cooling it is removed from the moulds and ground down to a fine powder.

The aluminous cement finds special uses since it is not attacked by sea-water, oils, peaty waters, etc., which are liable to corrode Portland cement. The setting time for aluminous cements is three to four hours.

Gypsum Plasters

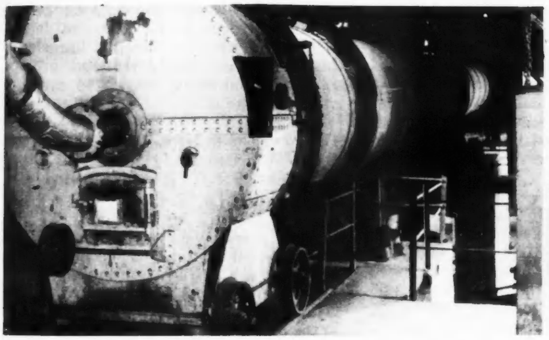
The mineral gypsum is a hydrated sulphate of calcium ($CaSO_4$, $2H_2O$). Its value in plaster making lies in the fact that if part of the water is driven off by heating, the partly calcined product will quickly re-absorb water and re-crystallise into a hard mass.

Workable deposits of gypsum occur in the rocks of Permian, Triassic and Jurassic age in Britain. The principal sources are from the Permo-Triassic rocks in the Vale of Eden, Cumberland, the Midlands and Somerset. Nottinghamshire is one of the country's most productive areas, especially in the region from Newark to Gotham. Here the gypsum occurs in the upper part of the Keuper Marl series, either in workable seams which vary from a foot to several feet in thickness, or in lens-shaped masses. The origin of gypsum is very interesting geologically.

Geologists have interpreted the conditions under which the rocks of the Keuper Marls and the gypsum series were formed. At the time the Keuper was being formed the greater part of the country was low-lying and had an arid climate. At one time an arm of an inland sea extended from Tynemouth—Newark—Gloucester to Watchet. Within this inland sea, which received desert dust stirred up by frequent sand-storms, the gypsum was precipitated from the calcium-sulphate saturated waters. The gypsum seams are not confined to one horizon but occur in two main levels; this indicates quite clearly that two inland seas must have existed and that rapid evaporation under arid conditions resulted in the waters being saturated with calcium sulphate. This is all that now remains of ancient seas which dried up millions of years ago.

Powdered gypsum heated to 170°C. loses 75% of its combined water. The product, when finely ground, is known as plaster of Paris; this possesses rapid setting properties and within half an hour sets hard. Plaster of

FIG. 4 (*left*).—Loading high-carbonate limestone at Waltham-on-the-Wolds for blending with Blue Lias limestone at Barnstone Cement Works for the manufacture of Portland Cement. FIG. 5 (*right*).—The Blue Lias low-carbonate limestone at Barnstone, which, in contrast to the Waltham limestone, is a dark grey-blue colour and much richer in clay materials. Using a drag-line the limestones are excavated after blasting, and loaded into wagons which are hauled to the works. This quarry is well known to geologists; fine fossils of creatures which existed 150 million years ago are often brought to light.



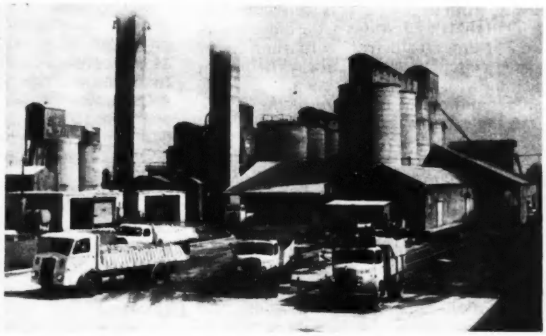


FIG. 6 (*left*).—The lower end of a rotary kiln at Barnstone. Pulverised coal enters the kiln by the pipe on the left-hand side; the cement clinker falls out of the kiln between the four wheels of the movable fixed end of the kiln before it passes on to the coolers and grinding mills. FIG. 7 (*right*).—A view of the Barnstone Cement Works where the first experimental rotary kiln was installed in 1885. The silos on the left are used for storing and mixing limestone after it has passed through the crushers, the central ones are for clinker whilst those on the right hold cement which is dispatched by road and rail. (*Courtesy of G. and T. Earle Ltd.*)

Paris as such is not used for building, but when retarding materials such as keratin are added, this plaster is ideal for moulding and pre-cast ornamental work. Retarded hemihydrate plasters, as this group are known, are sometimes used for undercoat work when they are mixed with sand in proportion from 1 : 1 to 1 : 3. ('Undercoat' in this connexion means the first plaster coat which is applied to cover rough brick before the final hard plaster is applied.)

Further heating of the gypsum drives off the water at temperatures of 200° C. This lightly burnt gypsum is mainly used for undercoat work and the same purposes as the hemihydrate plasters.

By increasing the temperature in the kiln, plasters which give harder and finer finishes are obtained. In hard-burnt anhydrous plasters there is no rapid setting and the plasters can be worked to a fine finish. They are used neat, and applied on top of Portland cement and sand undercoats. Since hard-burnt plasters take a long time to set, accelerators (such as potassium sulphate, alum or zinc sulphate) may be added to give a slow and continuous set. Best results are obtained when the plaster dries out evenly and slowly. Plaster board, which has practically replaced lath work for ceilings, consists of a core of gypsum plaster between felted fibrous paper rolled into $\frac{3}{8}''$ boards. Finishing coats of high-grade plasters are usually applied to plaster boards to fill the joints.

During recent years the minerals of the vermiculite group have become increasingly important in the manufacture of plasters, and other thermal and acoustic insulating products, as well as for light-weight concrete. This mineral, which is produced mainly in the United States and the Union of South Africa, has the remarkable property of expanding up to twenty times it original size when heated. The expanded product is not only very light but is an excellent sound and heat insulator. Vermiculite-gypsum plasters are much lighter than common gypsum-sand plasters and can even be sprayed on to walls. They are a pleasant gold colour and have been used in public halls, film and broadcasting studios. Since expanded vermiculite is not subject to oxidation, the bright colours do not tarnish. An article describing this mineral and its uses appeared in the August 1952 issue of DISCOVERY.

The cover photograph shows a rotary kiln at Swanscombe Cement Works, Kent; by courtesy of Cement and Concrete Association.

The Bookshelf

Flora of the British Isles. By A. R. Clapham, T. G. Tutin and E. F. Warburg. (London, Cambridge University Press, 1952, 1591 pp., 79 figs., 50*s.*)

WE have needed for some time a new book of convenient size, dealing with the seed plants and vascular cryptogams of the British Isles. Every field botanist has a soft place in his heart for Bentham & Hooker, Hooker, and Babington, but he knows that these books no longer fully meet his needs. They do not cover many plants which are quite common, they do not take account of the great volume of ecological and cytological knowledge which has accumulated during the present century, and they do not help him to name the many kinds of plants which have become established here, more or less firmly, from overseas. It is sometimes too evident that descriptions in the older books were at times made from herbarium specimens, a circumstance not always helpful in dealing with a living specimen.

The authors of the *Flora of the British Isles* are experienced members of the progressive school of British botanists; they are well acquainted with the plants as they grow, and familiar with the advances and changes which have occurred in their field of botany in recent years. In the preparation of their book, they have drawn largely on their knowledge of the live plants, they have incorporated a great deal of biological, ecological and cytological information, and they have fitted into place descriptions of a very large number of non-British plants, some at least of which now seem to be completely naturalised here. The book is well provided with clear keys, which testing shows will work. Undoubtedly this *Flora of the British Isles* is a very welcome addition to the equipment of the field botanist, and it is easy to use even by a reader with relatively little preliminary training; always provided the user is willing to put some work into his efforts.

Yet one or two grumbles are unavoidable. The authors seem to have been, perhaps, a little liberal in their treatment of the conifers. It is true that many of the species they include are now common enough in cultivation, but they can hardly be regarded as members of the British flora, nor does it seem very likely that they will become established as self-supporting members of that flora. Even so, the field botanist is likely to meet these plants, and it is convenient to have a ready means of identifying them, just as, to take a few examples at random, it is convenient to have readily available descriptions of such plants as *Arenaria balearica*, *Cerastium tomentosum* and *Helxine solierolii*, or of *Fuchsia magellanica* var. *riccartonii* and of *Carpobrotus* (*Mesembryanthemum*) *edulis*, both very familiar to visitors to the Cornish peninsula. So that convenience may outweigh formal precision.

A more serious grumble concerns the systematic names of the plants. We are still horribly afflicted with frequent changes of names, and there seems no sign that the end of that trouble is in sight. No doubt, changes are unavoidable if we are ever to have a stable and universally accepted list of names, and no doubt the authors can fully justify every name they have used in the book. Yet, without going into details, the elderly botanist will find a number of changes which he will regard as unwelcome, and he may find his thoughts straying to Chapter L, of the third book of Pantagruel, whence it appears, a little unexpectedly, that what is currently regarded as a modern plague is really a venerable nuisance. The passage is too long to give here, but in an uncharitable moment one could wish that the punishment inflicted by Ceres on Lyncus might threaten the whole race of name-changers.

The *Flora of the British Isles* is a most welcome book. It is already in wide use, and it will certainly stimulate active work on our plants as living organisms, and not as dry corpses on herbarium sheets; it is to be hoped that it will not encourage indiscriminate collecting. If and when it is completed by a volume of illustrations, the field botanist will be better served by his books than he has been for a long time.

B. BARNES.

Waves and Tides. By R. C. H. Russell and D. H. MacMillan. (London, Hutchinson's Scientific and Technical Publications, 1952, 348 pp., 25*s.*)

THOUGH the title of this book suggests a connexion between the two subjects, there are really two separate books within one cover. Each is written by an expert—Mr. Russell is engaged on research for the Hydraulics Research Station, and Commander MacMillan is the Hydrographic Surveyor to the Southampton Harbour Board.

Everyone of us has been fascinated by waves on the sea; many of us have argued about or accepted the old belief that the ninth (or seventh!) wave is always the biggest. Yet try as we will, we can find very little information about waves in any book except the mathematical text that gives equations and limits and boundary conditions in formidable array. The first part of this present book therefore satisfies a real need. Without shirking elementary mathematics (understandable to anyone of school-certificate standard), the author yet contrives to give a very readable account of wave phenomena. There is even a page on surf-riding. Anyone who wishes to distinguish between plunging breakers and spilling breakers, or to glimpse the complexities of interfering waves, or, in fact, get any information with which to answer intelligent children's persistent seaside questions is advised to study this part of the book, which has diagrams and excellent photographs.

The second part of the book is rather different. The subject is not inherently fascinating. Tides are in fact more usually sources of irritation to the layman, preventing him from sailing or bathing just when he wishes. To the person scientifically inclined and to the navigator they present problems to be solved. So we are not surprised when Commander MacMillan after a lyrical start and a historical introduction, plunges us into a list of technical terms and is soon discussing lunar and solar movements in all their complexity of inter-relations and is later involved in aspects of harmonic analysis as they affect tidal prediction.

This part of the book is in fact a text on a difficult subject. This being understood, we can appreciate the degree of the author's success. It would be difficult to find anywhere as serious a discussion of tides in such a short space as we find in this book.

The publishers were right in getting the two subjects into one composite book, but it seems a pity that there was no over-riding authority who could have made the authors correlate their discussions. Nevertheless the book is, to my knowledge, unique in presenting a readable account of these phenomena known to everyone who visits the sea. C. L. BOLTZ.

The Study of Instinct. By N. Tinbergen. (Oxford University Press, 228 pp., 130 figs., 25*s.*)

IN this book Dr. Tinbergen, an acknowledged master of his subject, sets out to fight the narrow views of the specialist and to weave them into a comprehensive approach to the study not only of instinct but of animal behaviour as a whole.

The difficulty he encounters is inherent in the nature of his task. He has to use the materials of those whose outlook he criticises to form the groundwork of his own web; furthermore, the new structure must be objective and possess none of the defects of the rejected systems.

In his criticisms of these other systems, Tinbergen limits himself at first to the confines of the particular field of innate behaviour—"behaviour that has not been changed by learning processes". He is concerned with the study of the causes of this behaviour and defines 'behaviour' as being "the total movement made by the intact animal".

The directive approach to the study of behaviour is exemplified by the work of E. S. Russell and W. McDougall. It maintains that the 'goal' or 'end' is the casual factor which controls the activities involved. Tinbergen rightly points out that while it is true to say that behaviour, like the workings of the kidneys and functioning of its blood, help to maintain the animal in a hostile world, the secondary and more detailed statement that the heart pumps in order to keep up a continuous flow of aerated blood to, for example, the brain, is inadequate. It does not say what causes are at work, at least not in terms which any physiologist would find acceptable.

Similarly those who describe animal behaviour in emotional terms are equally open to criticism. Hunger is "merely a guess about the possible nature of an animal's state". It is "a phenomenon that

can be known only by introspection". Yet Tinbergen recognises that studies using these approaches have contributed much that is of importance and value to our knowledge of behaviour. His plea is that the nature of these approaches be recognised by those who adopt them and also the fact that they do not explain the causal details of the phenomenon they describe.

Tinbergen's criticism of what he terms the "other causal sciences of behaviour" is rather different. The neurophysiologists are working at too low a level to appreciate the great complexity of even the relatively simple instinctive actions. They belong to a much "higher integrative level" than those at which the neurophysiologist, the sense physiologist and the muscle physiologist carry out their work. The behaviourists are criticised for their tendency to concentrate on the non-innate forms of behaviour when they study animals. They are too interested in finding primitive (i.e. pre-human) elements of behaviour in animals and of being influenced too much in their studies by regarding them as preliminary studies, in the evolutionary sense, into the behaviour of man.

Without a thorough knowledge and understanding of innate behaviour, non-innate behaviour, Tinbergen claims, cannot be adequately examined and comprehended. Loeb, Jennings and many others are openly criticised for what indeed is the greatest failing of so much modern science—too great generalisations from too limited and specialised experimental and observational work.

Behaviour is reaction in so far as it is the response to external stimulation, and it is spontaneous in so far as it is dependent on internal causal factors for the activation of an urge or drive. The reflexologists and the psychologists are both partly right. Both aspects can and should be studied objectively.

Before attempting a synthesis of his own views, he cites a vast mass of relevant experimental findings. For example, the experiments with models which showed Lorenz and Tinbergen how ordinary birds recognise birds of prey by their short necks; the mating behaviour of the sticklebacks; the reaction of the hen to the call of the distressed chick she can't see and the lack of reaction to the silent one, equally distressed, which she can see, are all described in their appropriate places. The experiments on implantation of limbs by Weiss and on the locomotory movements of sharks after the afferent nerves have been cut are all brought into the story.

There is a constant cry throughout of not enough exact detail coming from such experiments for us really to know what happens. And the well-timed warning of the wise scientist: do not just follow a specialised study, know all you can about the animals you use in your experiments, flows throughout. One good example of this is seen in *Dytiscus marginalis*, the water beetle, which has remarkably well-developed compound eyes, but hunts its prey by scent, not sight, as many would suppose. The clue to Tinbergen's own outlook to all this behaviour is to be found in a quotation from von Holst which he uses. It is amusing and worthy of requoting: "The nervous system therefore is not like a lazy ass that has to be beaten or rather has to pinch its own tail before being able to do one step, but rather like a temperamental horse that has to be kept in check by the reins and urged by the whip." Each separate reaction has an "Innate Releasing Mechanism" (I.R.M.). These Innate Releasing Mechanisms are arranged in a hierarchy. Each I.R.M. has its own motor pattern which is released when it is stimulated, but sometimes only a lower level in the scale of the I.R.M. hierarchy will be affected by an external stimulus, and at other times one higher in the scale. An external stimulus can thus release a major response involving the complete pattern of reproductive behaviour, or it may release only a part of it, such as fighting, nesting, etc. The "appetitive behaviour" of an animal is just as much controlled by such a mechanism as the more stereotyped consummation. The running of a maze by a rat is appetitive behaviour of this order—it runs not to find the goal, but to find the conditions under which it can consummate the act for which it set out—actually to masticate and swallow the food. The running must go on until either the consummation is achieved or until the appetitive behaviour weakens its hold. In the latter event some form of 'displacement activity' such as cleaning itself or going to sleep, takes the place of the appetitive behaviour and destroys the chain which would only otherwise end in the strictly patterned consummation.

The whole of instinctive behaviour in this way becomes a successional series of breakings through of 'blocks' at different levels of the nervous system. Appetitive behaviour goes on until one of the I.R.M.s at a lower level removes a block letting the energy utilised in this higher level of behaviour down into the lower consummatory level and thence, after the removal of the last of these higher blocks, straight through to the various levels of co-ordination which control the actual muscles of the body.

The whole structure of this hierarchy of releasors is, as Tinbergen admits, only a convenient descriptive mechanism. Certainly it has so far proved a most valuable stimulus in directing research into animal behaviour along less hidebound and more fruitful lines than in the past. It will no doubt in turn be replaced by a more permanent and less sketchy approach, for at the moment it can only be regarded as a temporary structure of the right type. As Tinbergen says, we know too little—there is too little data of the right quality.

But if only his commonsense outlook can have the influence on students which it deserves, then the study of Animal Behaviour may well be approaching its Golden Age. If this is to be, then the lessons he points out must be well and truly learnt. The important question facing the student is the obtaining of detailed objective knowledge capable of being welded to the research of others in order to form a part of the larger picture.

Tinbergen's book is the sanest on animal behaviour that I have ever read. If common sense prevail, then the falling of individual theories—even of Tinbergen's—is of little count.

DEREK WRAGGE MORLEY.

Far and Near

The Biology of Deserts

SOME interesting reports of new research were heard at the international symposium on the Biology and Productivity of Deserts, which was organised by the Institute of Biology in conjunction with Unesco, and held at the Royal Institution in September.

Though there was some mention of the cold deserts and their special problems, the conference concentrated on the progress of what might be termed "Hot Desert Research". The need for special research into problems of life in the arid-hot deserts and into the problems of bringing the deserts to life and making them habitable was stressed throughout. The reports of research already done served the additional function of underlining this need by exposing the vast gaps which exist in our knowledge.

The work of Dr. Knut Schmidt-Nielsen and his wife, Dr. Bodil Schmidt-Nielsen, into the water conservation and heat regulation in small desert mammals clearly emphasised this point. Specially adapted rodents are found in all deserts, and it has long puzzled scientists how they managed to survive in such arid regions. Typified by the Jerboa of North Africa (*Jaculus aegyptus*) and the Pocket Mouse (*Perognathus*) and Kangaroo Rat (*Dipodomys*) of Central and North America, these rodents all have long hind legs, short front legs and long straight tails. Although desert rodents come from a number of different families, often quite unrelated, they all show these characteristics: also they all make the same type of large, many-entranced, subterranean burrow. These rodents thrive under conditions which are so arid that no other mammals can survive.

In their researches these workers found that the whole water supply of *Dipodomys* and *Perognathus* is obtained from their bodily metabolism and the pre-formed water already in their bodies. Experiments showed that for each 100 calories of body metabolised they formed 13·4 gm. of water—an amount much greater than that in the grain needed to produce the 100 calories. The rate at which they lose water by evaporation is much less than in water-drinking mammals. Evaporation from rodents (as from dogs), is not by

means of perspiration through the skin, but takes place mainly from the lung surfaces through breathing. But the loss of water in this way in *Dipodomys merriami* is only half that in the laboratory rat, this is because of the low temperature maintained in the animal's nose, which is 10 degrees lower than that of the rest of the body; the moist air from the lungs is cooled, and water condenses in the nose, whence it is returned to the body.

These desert rats and mice also produce very dry faeces; little water is excreted, and the urea and electrolytes in the urine reach much higher concentrations than in most mammals.

Fed on a soya bean diet which increased the amount of urea they produced even further, they still at first refused water, seemingly not knowing how to drink. But after a few days they started drinking and then lived happily not only on fresh water, but also when they were supplied with salt water instead.

The humidity of their burrows was estimated, and was found to be of the order of 10 mg. per litre as against 2 mg. per litre in the desert outside.

Jerboas and Kangaroo Rats can live quite happily when the relative humidity is over 24% at 25 C. When placed under conditions of 15% and 10% humidity, they just managed to maintain their weight, but at 5% humidity they lost weight. This is in strong contrast to what one finds with laboratory rats, for example; these always have a water output that is greater than the intake and even under conditions of 100% relative humidity, they must drink water to maintain their fluid balance; they lose weight when prevented from drinking.

The maintenance of the water balance and the need for body temperature control through evaporation, are important factors which affect the ability of mammals of every kind to survive under the hot and arid conditions found in deserts. Yet little is known about the matter in most animals, including man. There seems to be a general law which links evaporation with size, the evaporation rate increasing greatly with the decrease in size of the animal, but the matter needs fuller investigation. The fur of the small animals certainly plays an important part in insulating them from excessive heat, and research into the importance of clothing in the case of man should be undertaken.

Similar queries were raised by Dr. Norman C. Wright in his paper on the domesticated animals inhabiting deserts. Schmidt-Nielsen has demonstrated that the larger-sized animals have a relatively smaller evaporation rate thereby contradicting Bergman's rule (which says that animals have larger body size in colder climates and smaller body size in warmer ones). Dr. Wright's observations on the typical sheep and cattle of the arid desert regions support Schmidt-Nielsen's conclusions. The cattle of the desert and semi-arid areas are among the largest in the world. For example, the Zebu bull is especially large and has an exaggerated skin area. These cattle have excellent beef potentialities. Similar characteristics are found in the Sudanese cows which should be developed for their excellent milking qualities. Their milk has a 6–8% butter-fat content, and a lactation of nearly a thousand gallons is usual.

Dr. Wright argued against the attempt to interbreed desert and non-desert stock. The desert stock had all the potentialities, and should be improved by selection without crossing them with non-desert stock.

The papers on human physiology seemed to contain little that was new, with the exception of a report by Dr. Edholm. He pointed out that life in the cold deserts involved a higher calorific demand. For each degree Fahrenheit drop in temperature, an extra 15·5 calories are required if the amount of work undertaken is to be maintained. This is in part due to the hampering nature of Arctic clothing.

The entomologists, led by Dr. Uvarov, the locust expert, had little but warnings to offer. Increase in cultivation on desert fringes and around oases would, they suggested, be outweighed by the encouragement given to pests; the desert locust would have more and better breeding grounds and insects that normally do little harm, would feed on the newly established crops.

A different point of view about harmful insects was that expressed by Professor Phillips. The tsetse fly, he said, was invaluable because it limited cultivation in a way that might be regarded as beneficial. Where the tsetse fly is controlled, new and better techniques of farming must be established or, as had already happened in many of the areas which have been cleared of tsetse fly, man-made deserts would result in a matter of a few years after clearance.

The degree to which the deserts are man-made was queried by the geographers. If they are man-made, then the reversal of the process which created them is not such a difficult matter, but if (as is true in most cases), they are *not* man-made, then the position is well-nigh impossible.

Professor Shotton of Birmingham University held out little hope for large-scale irrigation—a necessity if the desert is to be recovered for agriculture. Deep water supplies for artesian wells are all too rare and most are already over-exploited. Other water supplies are too saline. While man can tolerate 3000 parts of NaCl per million, and cattle and sheep up to 14,000 parts per million, the limits of toleration in plants is about 100–200. But he felt nomadism should be encouraged—the breeds of the nomad herds should be developed and the people aided, for at least it brought the best return possible at present from the desert areas.

* * *

Immediately after the Institute of Biology's conference the Unesco Advisory Committee on Arid-zone Research met at the Royal Society. They heard reports from a team of plant ecologists, discussed the collection of fresh information about desert research, and briefly considered the possible sources of power that could be harnessed in desert regions. Used during this meeting was a new and useful series of maps of the eastern and western hemispheres prepared to show the zoning of semi-arid, extremely arid and arid areas throughout the world.

One spokesman at the Unesco meeting said that the committee is more concerned with "the collection of information about already existing research rather than instigating new research". There are, however, other experts in this field who see a great need for more research to be done.

Sir Richard Gregory (1864–1952)

SIR RICHARD GREGORY, F.R.S., who died on September 15, has a permanent and living memorial in *Nature*, the most famous scientific journal in the world. His association with that unique magazine went back to 1893, and continued for 46 years. During that period he was the driving force behind *Nature* and under his editorship it gained its unique and influential position in the scientific world.

It was not until the age of twenty-one that Richard Gregory received any formal scientific education. He had begun work at the age of twelve. After several years in a boot factory, he found himself a job as laboratory assistant at Clifton College, where he came under the sympathetic eye of the late Prof. A. M. Worthington, a science master who had studied physics under Helmholtz in Berlin. It was his success in the 1885 examinations of the Science and Art Department which took Sir Richard to the Normal School of Science (now the Royal College of Science) in the January of the following year.

His classmates at the Normal School included H. G. Wells (who became his lifelong friend) and F. W. Lanchester.

When he left the college in 1887, he became science demonstrator at H. M. Dockyard School, Portsmouth. His next post was as personal assistant to Sir Norman Lockyer who, besides lecturing at the Normal School, was in charge of the Solar Physics Laboratory that stood on the site now occupied by the Science Museum.

Then came a short spell spent as a freelance, when Sir Richard lived by his writings and by giving university extension lectures. After two years as a free-lance he received a letter from Lockyer asking him to call. Some thirty years previously Lockyer had founded *Nature*, and now he found himself in need of a new assistant editor. He offered the post to Gregory, who accepted it without delay, to start his career with the paper with which he was to remain for forty-five years, and of which he was to become editor when Lockyer relinquished the editorship in 1919. During those years he saw over two thousand weekly issues of *Nature* through the press.

The service he rendered to the scientific community through *Nature* were recognised in 1933 by his election as a Fellow of the Royal Society.

While he was editor of *Nature*, Sir Richard used to act as adviser on scientific text-books to his publishers, Macmillans. He has many shrewd ideas about the type of books that teachers and students

require. One example of a happy inspiration of his is *Duncan and Starling*. It was his suggestion that an engineer and a physicist should be brought up together and produce a physics text-book: *Duncan and Starling* was the result.

The fact should be recorded that it was Sir Richard's book *Discovery, or the Spirit and Service of Science* which first suggested the title of the journal you are reading. It was the original publisher of DISCOVERY John Murray, who had the idea and who obtained Sir Richard's permission to use the name on the cover.

Night Sky in November

The Moon.—Full moon occurs on Nov. 1d 23h 10m, U.T., and new moon on Nov. 17d 12h 56m. The following conjunctions with the moon take place:

November				
2d 15h	Jupiter in conjunction with the moon	Jupiter	7°	S.
15d 06h	Saturn ,,	Saturn	7°	N.
19d 03h	Mercury ,,	Mercury	2°	N.
20d 11h	Venus ,,	Venus	1°	N.
22d 05h	Mars ,,	Mars	0·2°	S.
29d 17h	Jupiter ,,	Jupiter	7°	S.

The Planets.—Mercury is an evening star, setting a little more than half an hour after the sun in the first half of the month, but is too close to the sun for favourable observation, and on Nov. 30 is in inferior conjunction, when it sets about the same time as the sun. Venus sets at 17h 50m, 17h 55m and 18h 20m on Nov. 1, 15 and 30, respectively, and is a conspicuous object in the western sky, stellar magnitude $-3{\cdot}5$ and more than three-fourths of the illuminated disk being visible. Mars sets about 20h 05m throughout the month, stellar magnitude 0·9 to 1. As the planet's declination is far south it does not rise very high above the horizon and this will make good observation difficult. Jupiter is visible throughout the night and sets in the morning hours at 7h 40m, 6h 30m and 5h 20m at the beginning, middle and end of the month, respectively. Its stellar magnitude is $-2{\cdot}4$ and it lies a little south of δ Arietis. On Nov. 8 the planet is in opposition to the sun, that is, the earth, sun and Jupiter are nearly in a line, and, as might be expected, Jupiter then sets about the time of sunrise and rises about the time of sunset. Saturn, a morning star, rises at 5h 10m, 4h 20m and 3h 30m on Nov. 1, 15 and 30, respectively, stellar magnitude 1. It lies a little north of the bright star Spica which is a little fainter than Saturn.

On Nov. 30, the 3rd magnitude star η Tauri is occulted by the moon at 17h 28·5m (that is, at 5.28½ p.m.) and reappears at 18h 21·7m. These figures apply to Greenwich but do not differ very much from the times in other parts of the country. As full moon occurs on Dec. 1 it may be a little difficult detecting the star but binoculars will assist. The star will be seen approaching the eastern limb of the moon, which is the limb on your left as you look at it, and after disappearance, remains hidden behind the moon for about 53 minutes. At Edinburgh the occultation commences over 6 minutes later and ends

(*Concluded on next page*)

Scientists and the Press: A P.R.O. Replies

MR. DEREK WRAGGE MORLEY'S article "Scientists and the Press" in the October 1952 issue quite correctly stated that there has been a gradual development of understanding in the last few years. This is all to the good of science reporting. Responsible people want responsible science reporting. They recognise the importance of science and its potentialities for changing their lives. This is not to say, however, that they want the scientist treated as an oracle, an authority on every subject, social and moral, as if he had a monopoly of intelligence and foresight. Some scientists are only too ready to assume this role and the papers to report their remarks, however irrelevant.

Mr. Morley produces some threadbare comments at the end of his article, unfortunately. After saying, quite wrongly, that the P.R.O. is only a wartime survival, he goes into the attack, taking his arguments directly from the columns of the Beaverbrook Press. He has not taken the trouble to think the thing out for himself

He starts by saying that the P.R.O. is a buffer, a hoary charge apparently directed against Government P.R.O.s. He accuses the P.R.O., by his very understanding of the Press, of preventing the success of a journalist's inquiries.

In fact, and these comments are based on long experience of dealing with scientific news in a Government department, most of the time the P.R.O. is fighting the journalist's battle. The scientist can always find reasons why his work should not be reported to anyone except fellow scientists. Overcoming this prejudice is the P.R.O.'s daily problem. The man in the street has every right to be told about scientific development. It may, and probably will, affect the society in which he lives. In any case, he is probably paying for it, either directly or indirectly. The journalist is the only person who can tell him about it in language he can understand. These arguments often achieve results but the P.R.O. is discouraged from advancing them when he is attacked by the very people he is trying to help.

Unfortunately, some of the reports that appear in the Press make the P.R.O.'s job more difficult by antagonising the scientist. The particular research worker may be presented as a super-conjuror able to bring about an industrial revolution overnight and change the face of Britain by a single piece of work. This may be due to the work of sub-editors, but it makes the job of the P.R.O. harder because scientists are, rightly, jealous of their prestige. They don't like being laughed at by colleagues.

It is obvious that Mr. Morley means to imply that generally Government P.R.O.s are unhelpful and obstructive, while the commercial P.R.O. may be a paragon of extra aid and liaison. This is not true at all. It is not difficult to think of reasons why a firm should be less willing to release information than almost any Government department. The commercial firm lives in a competitive world in which it may not pay to announce technical advances prematurely. It might prejudice a patent, for example, or create a demand for something which is not yet available on the market.

Many journalists find that, contrary to Mr. Morley's opinion, Government P.R.O.s in general are more co-operative than commercial P.R.O.s in supplying information to the journalist and in putting him in touch with an authority.

However, the chief failure of the P.R.O., says Mr. Morley, is his inability to understand that science news is detailed scientific fact of a kind that only the specialist writer can assess. Mr. Morley continues that all too often handouts are naïve and inadequate. We must be clear on what a handout is supposed to do. First of all it should interest a news editor, who is not a scientist. There are very few science writers in Fleet Street, as Mr. Morley points out, and the handout would not get very far if it was aimed merely at them. It has to be simple and it has to have something worth saying. Any science writer with news sense should know whether it is worth following up. The prime purpose of a handout is to indicate that there is a story for the getting. The science writer can quite easily get more detail from the P.R.O. If that is not enough the P.R.O. will put him in touch with the scientist who knows all the technical details, and, indeed, will generally prefer to do so. The P.R.O. will perhaps have to persuade the scientist to talk to the journalist, but that is part of his job.

P.R.O.s get quite enough denigration from Fleet Street because they are supposed to be doing the journalist's job for him. Mr. Morley is on a different tack. He says that the trouble with the P.R.O. is that he is *not* doing the science writer's job for him. He complains that he has to find out for himself something about the story, whatever it is. He has, to quote Mr. Morley, "to draw on the corpus of his own scientific knowledge and that of his scientific contacts". Surely this is what a newspaper pays a science writer to do, not to paraphrase or re-write a handout. It does not seem to have occurred to Mr. Morley that all he has to do is talk to the scientist who is doing the work. He says that if the handout does not give him all the relevant facts and special points to fit the news item into the proper background the laboratory has only itself to blame if it is disappointed with the results. Has it? Why can't Mr. Morley find out something for himself or does he, as a science writer, consider himself above asking questions?

Perhaps Mr. Morley will scout this idea, but it is just possible that the improvement in the relations of the scientist with the Press is, at least in part, the result of the P.R.O.'s work.

(The identity of the P.R.O. who contributed this letter is known to the Editor. We prefer to print Letters to the Editor above the writer's names but in this instance we are satisfied that there is no alternative to anonymous publication.)

nearly 9 minutes later. The reason why occultations do not appear at the same instant all over the country is because the moon is comparatively close to us—240,000 miles away—and hence appears displaced in the heavens with reference to the stars (which are hundreds of millions of times farther off than the moon) when viewed from different parts of the earth.

The Potency of 'Roccal'

We have received the following letter from Bayer Products Ltd. Africa House, Kingsway, London, W.C.2:

"We fear that a statement made about the purity of our antiseptic, 'Roccal', by Mr. R. W. Richards in his article in the September 1952 issue, entitled 'Germs Defeated', is liable to misinterpretation.

"The antiseptic potency of 'Roccal' is considerably higher than that of 'Zephiran' which this Company imported from Germany prior to the war. The active ingredient of 'Roccal' is Benzalkonium Chloride of U.S.P. quality. Benzalkonium chloride as used in 'Roccal' has a Rideal-Walker coefficient of 400, and 'Roccal' is a 1% solution of this substance with a Rideal-Walker coefficient of 4. 'Roccal' is now extensively employed in hospitals in Britain for skin sterilisation, obstetrics, and the sterilisation of hospital linen, instruments and appliances.

"Possibly the confusion may have arisen because the name 'Roccal' is used in the United States for a technical grade of Benzalkonium chloride with a lower Rideal-Walker coefficient."

Yours faithfully,

L. M. Spalton,

Bayer Products Ltd.

The Fulmer Research Institute: Five Years of Sponsored Research

Many scientists and industrialists visited the Fulmer Research Institute, Stoke Poges, on September 30, when an open day was held to mark the completion of the first five years' work. A memorial plaque was unveiled by Sir Archibald Rowlands to the late Colonel W. C. Devereux, who was largely responsible for getting this enterprise started in 1946. The purpose of the Institute, which was founded with aims similar to that of the Melton Institute in the U.S.A., is to carry out sponsored industrial research, the results of which—including any patents arising therefrom—belong solely to the sponsors. From the outset it was decided that the Institute should be non-profit-making in the sense that no dividends should be declared to the shareholders, any excess of income over expenditure being ploughed back to provide greater or improved research facilities.

The success of this enlightened experiment is evident from the remarkable expansion which has already taken place. In five years the staff has doubled, the income has trebled, and eighty-eight patents have been taken out on behalf of sponsors. The latter now exceed a hundred and include the Admiralty, various branches of the Ministry of Supply, British Railways, a number of Research Associations, and many leading industrial concerns (including the largest aluminium-producing companies in the United States and Canada). The income from British industry has steadily increased and is at present about £10,000 a year. Over the first five years the institute's total income exceeded a quarter of a million pounds; 52% came from Government departments, direct dollar earnings from Canada and the United States represented 11½% and British industry contributed 36½%.

The Institute has been staffed and equipped primarily to deal with metallurgical problems, but many problems in other fields have also been investigated. As examples of successful developments arising from research at Fulmer may be mentioned aluminium-copper-cadmium alloys, a new series of aluminium-tin-bearing alloys containing about 30% tin, and an entirely new method of producing aluminium of high purity. Under the sponsorship of the National Gas Turbine Establishment, much work has been done on the problem of distortion and cracking occurring in the combustion chambers of gas turbines. Low emissivity coatings have been developed to overcome the effects of heating by radiation, and patent protection has been applied for. Work is also being carried out on coatings for protecting the metal of the combustion chamber from oxidation. Research is proceeding on new methods of producing titanium, beryllium and other metals, as well as metal ceramics. The results of much of this work are of a confidential nature. Many special testing programmes have been carried out, often with apparatus specially designed and built at the Institute.

Increased laboratory space for physical chemistry and calorimetry has recently been provided, while plans for a new mechanical testing, creep and engineering laboratory are well advanced.

Printed and Published in Great Britain by Jarrold & Sons Ltd. Norwich *Editorial Offices: 244 High Holborn W.C.1*

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